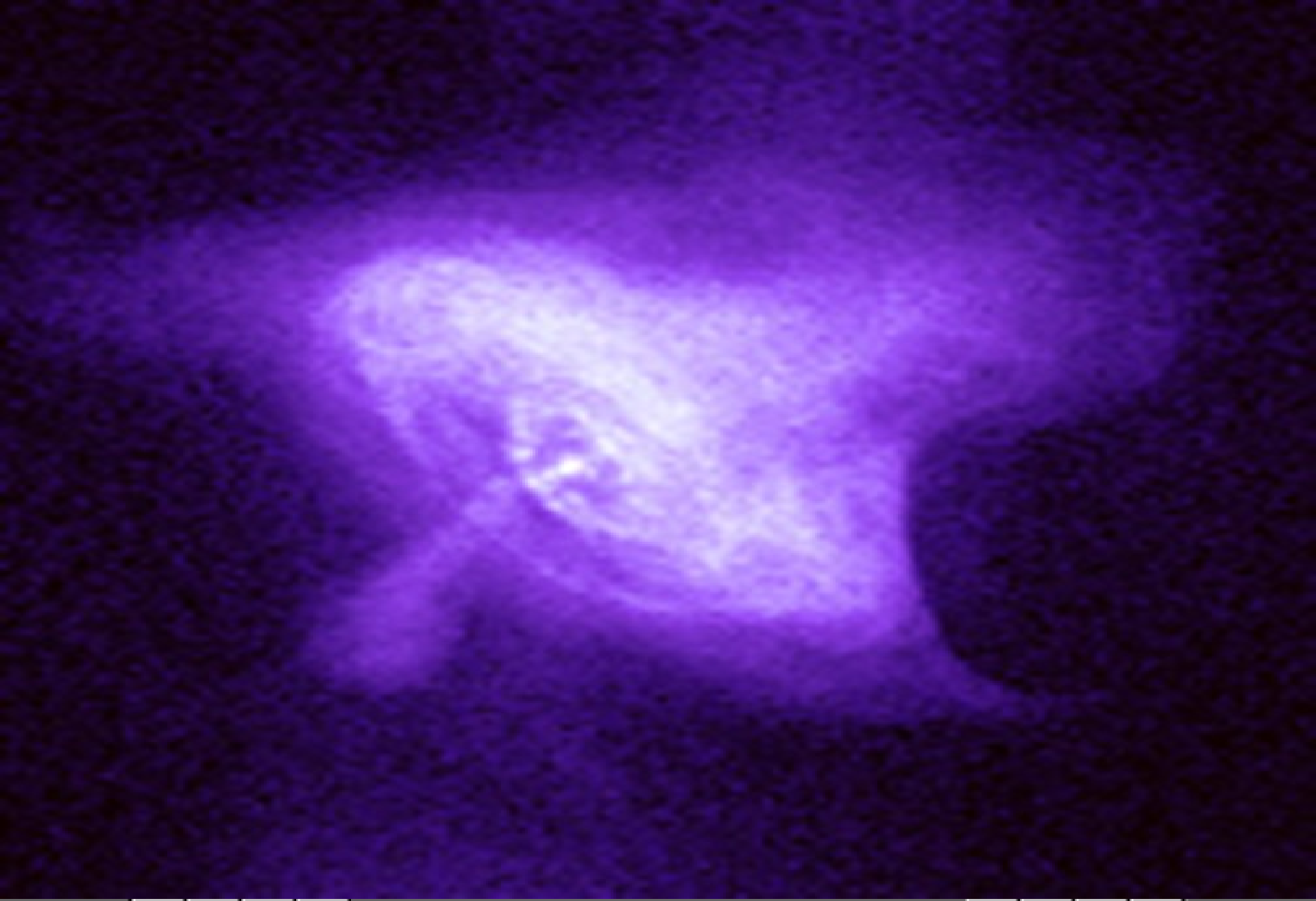
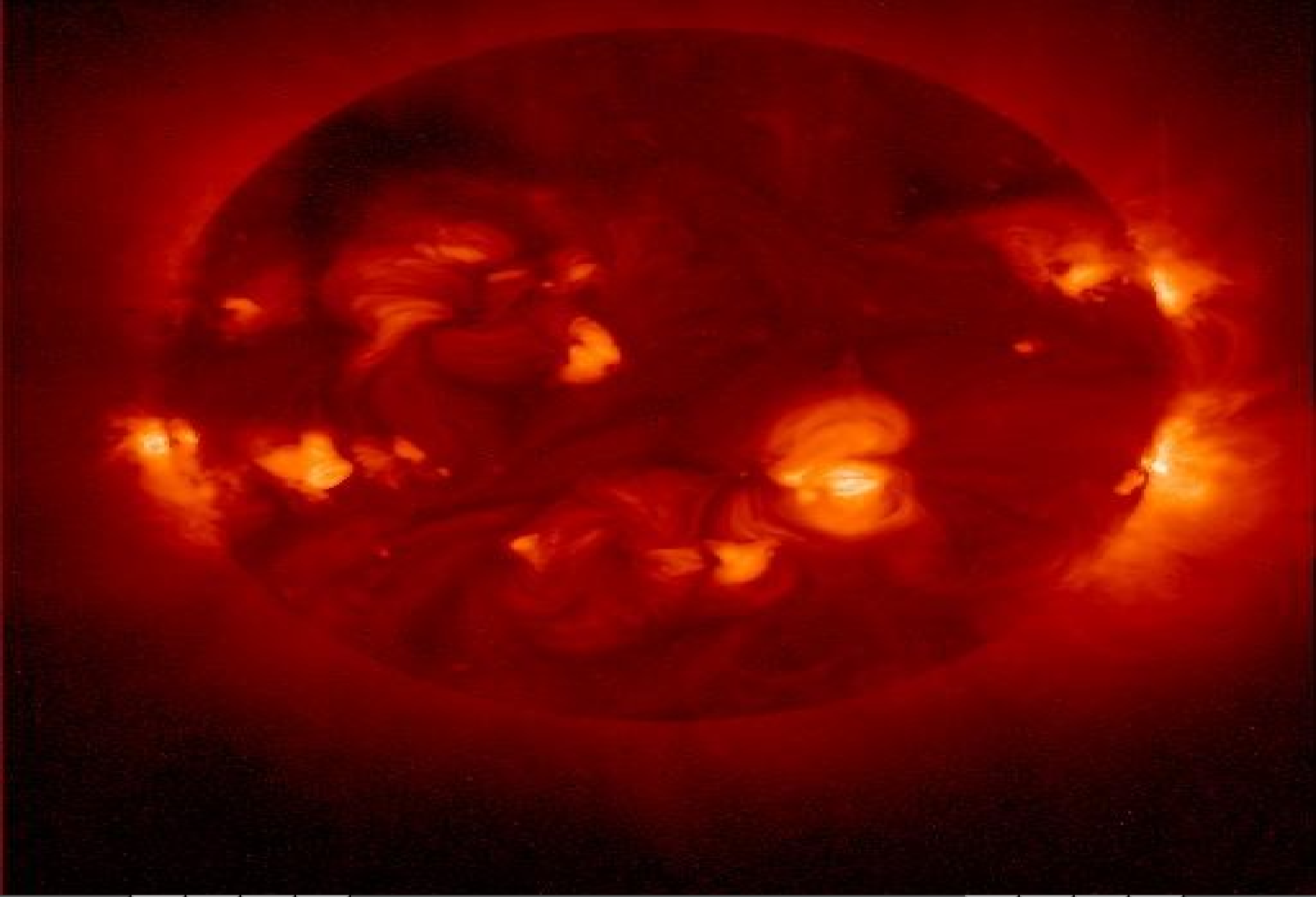
Satellite Meteorology

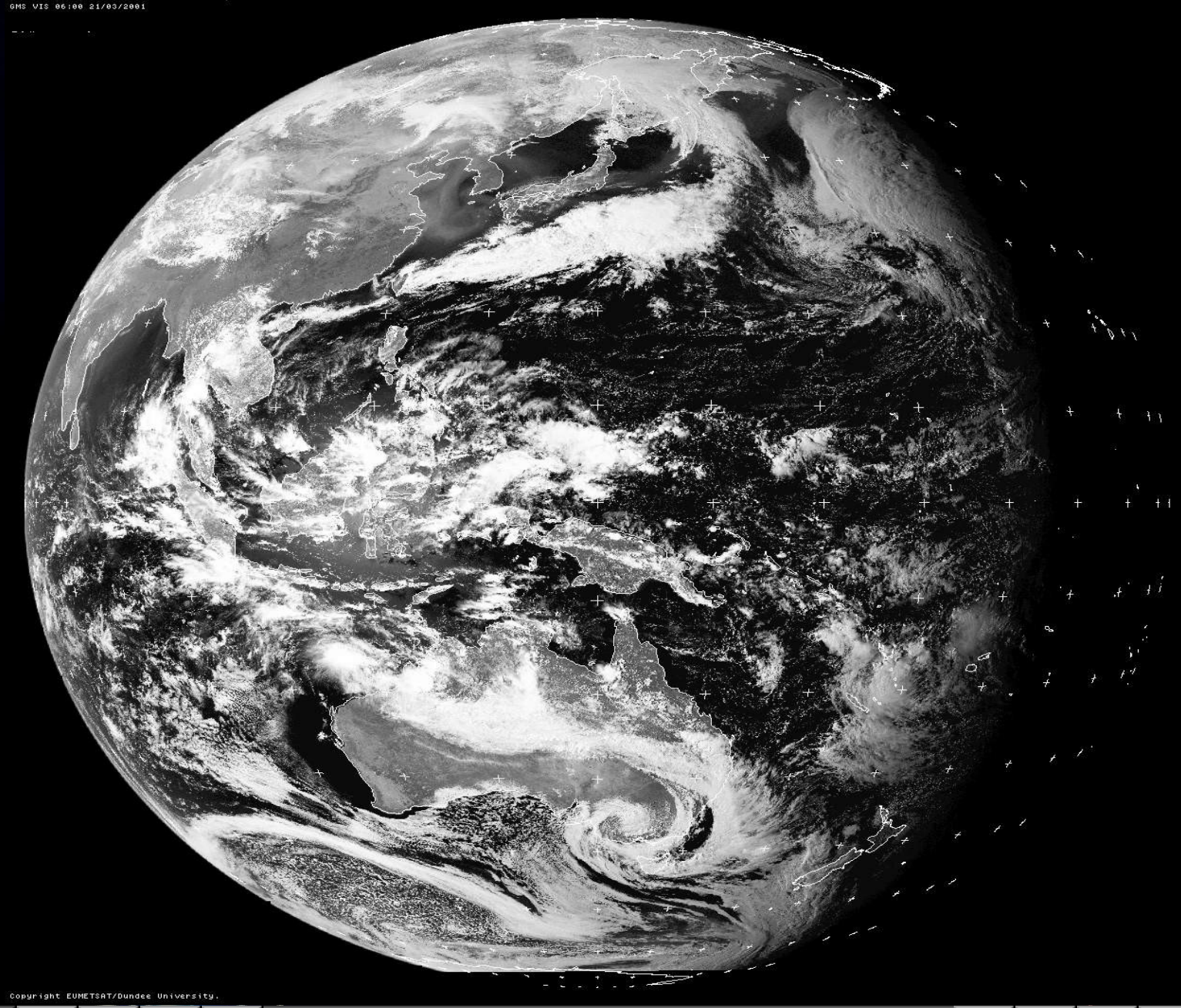
Remote Sensing in the Atmosphere

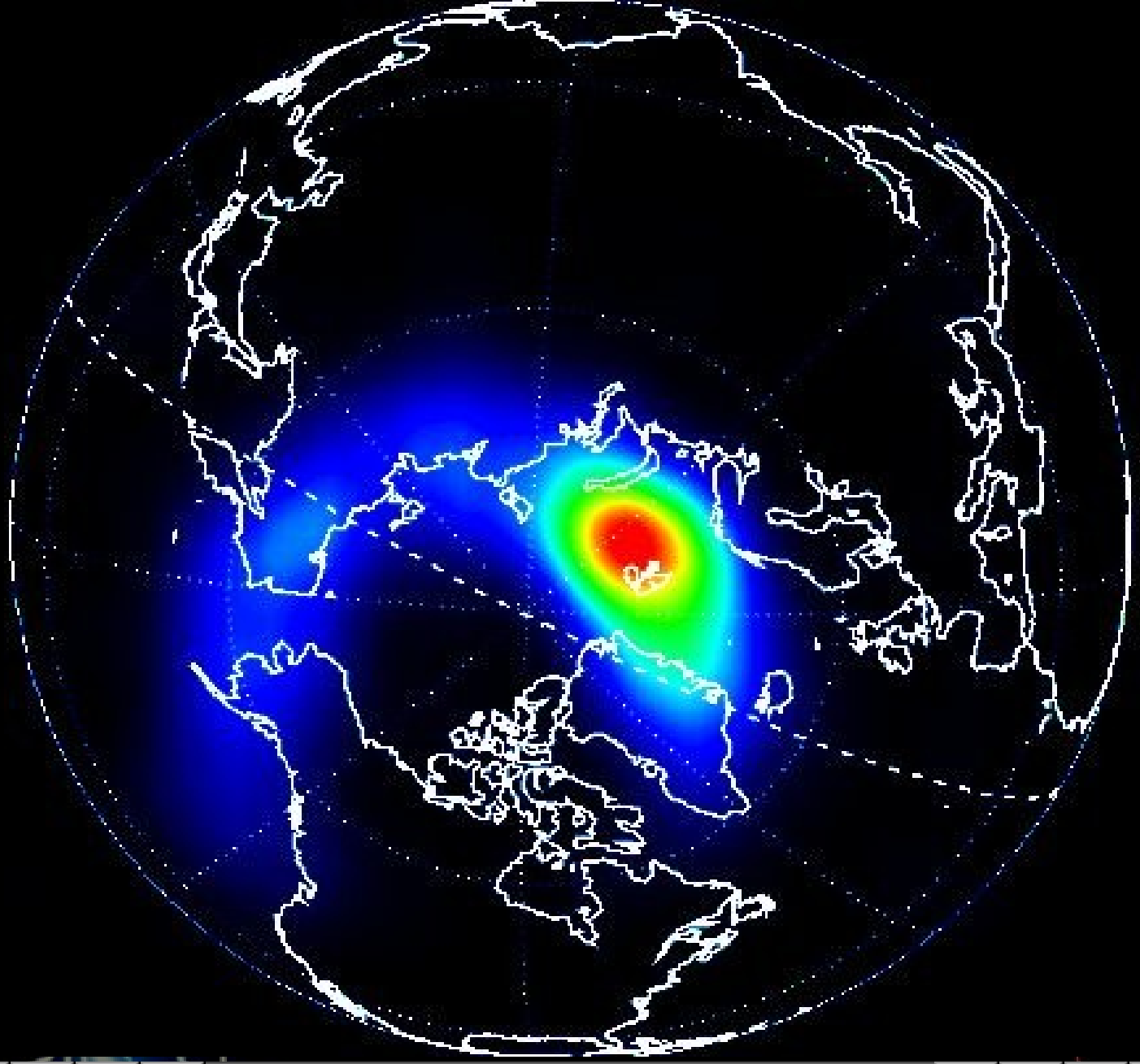
Part I

Determine System Capabilities and Viewing Considerations of Satellite Imagery.






GMS VIS 06:00 21/03/2001
Copyright EUMETSAT/Dundee University.



Overview

- Introduction to satellite concepts
- Short introduction to theory
- Basics of visible and infrared interpretation

Satellite Concepts

- Viewing considerations
- Imaging tools
- Theory
- Differences between visible, infrared, and water vapor images

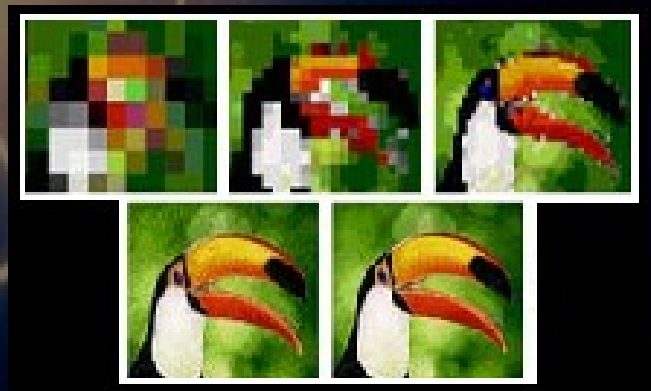
Viewing Considerations

- Resolution - spectral, radiometric, spatial, temporal

Viewing Considerations

- Foreshortening - loss of resolution caused by oblique viewing angle resulting in distortion

Resolution: 4 Types



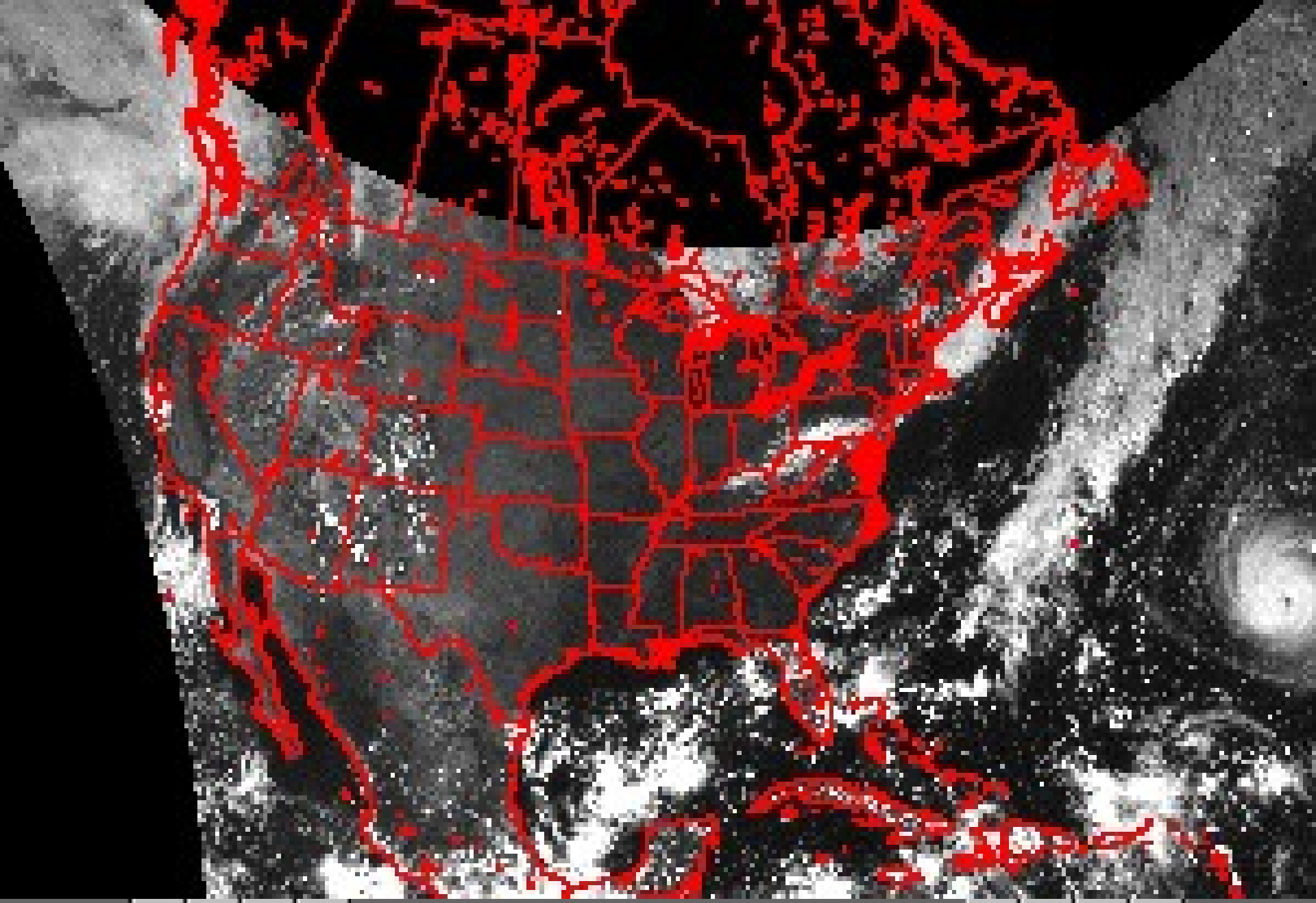
- Spectral
  - Number of bands in the spectrum in which the sensor can take measurements (Landsat, 7 channels; AVIRIS imaging spectrometer, 224 channels)
- Radiometric
  - Sensitivity to small differences in the radiation of an observed object (Landsat, 8 bit; ERS 16 bit)

Resolution Cont.

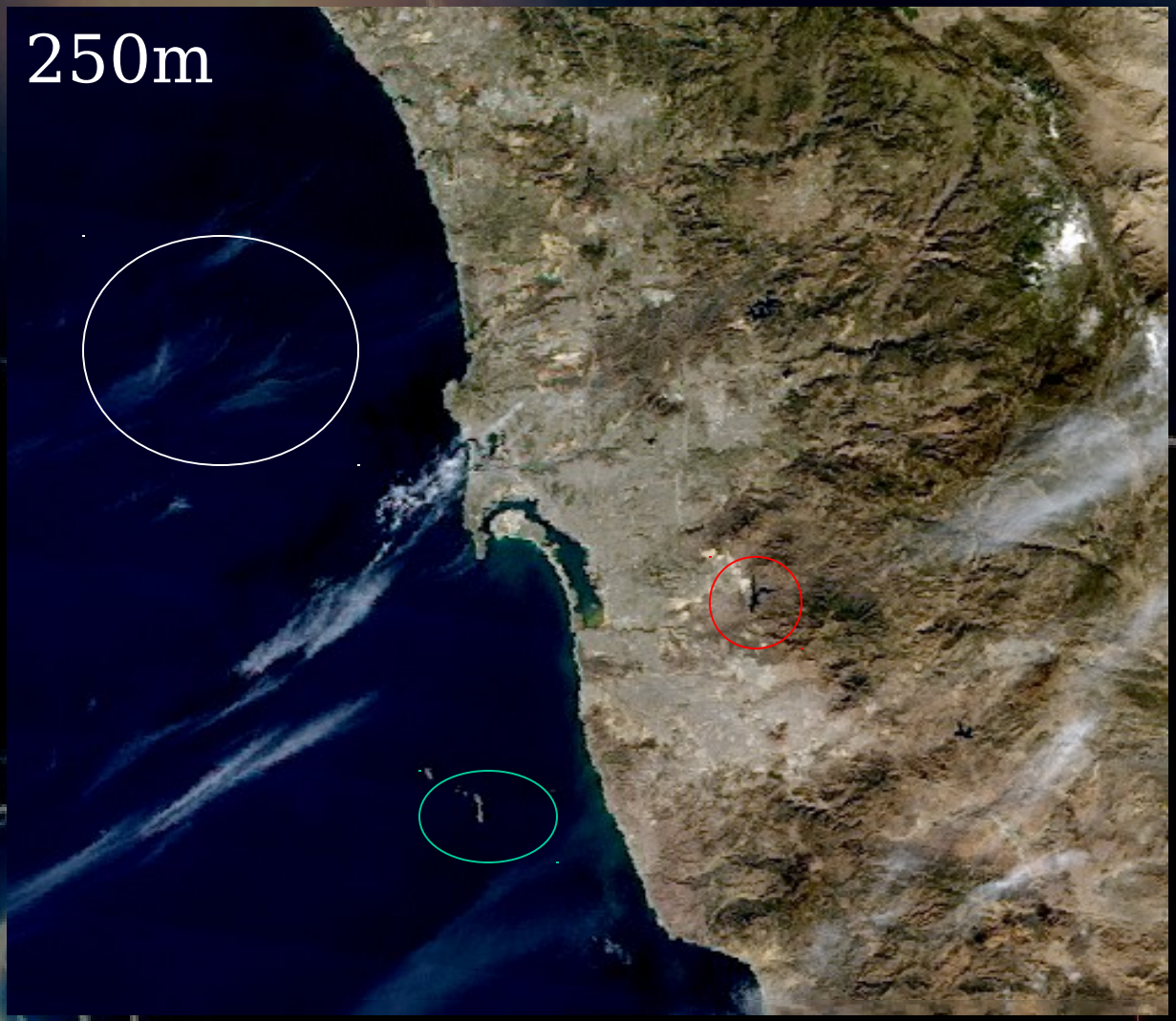
- Spatial
  - The smallest individual element that a sensor can see. The best resolution is always directly beneath the satellite. Ability of the sensor to detect and distinguish small objects and fine detail (Landsat 30 m, OLS 600 m, Meteosat 7 km, spy satellites 2 m)

Resolution Cont.

- Temporal
  - The frequency with which a satellite can revisit an area of interest and acquire a new image. (Landsat, 16 days; GOES SRSO, 30 seconds to 1 minute)
- Shorter wavelengths provide better resolution than longer wavelengths. (Visible better than IR)



Spatial Resolution



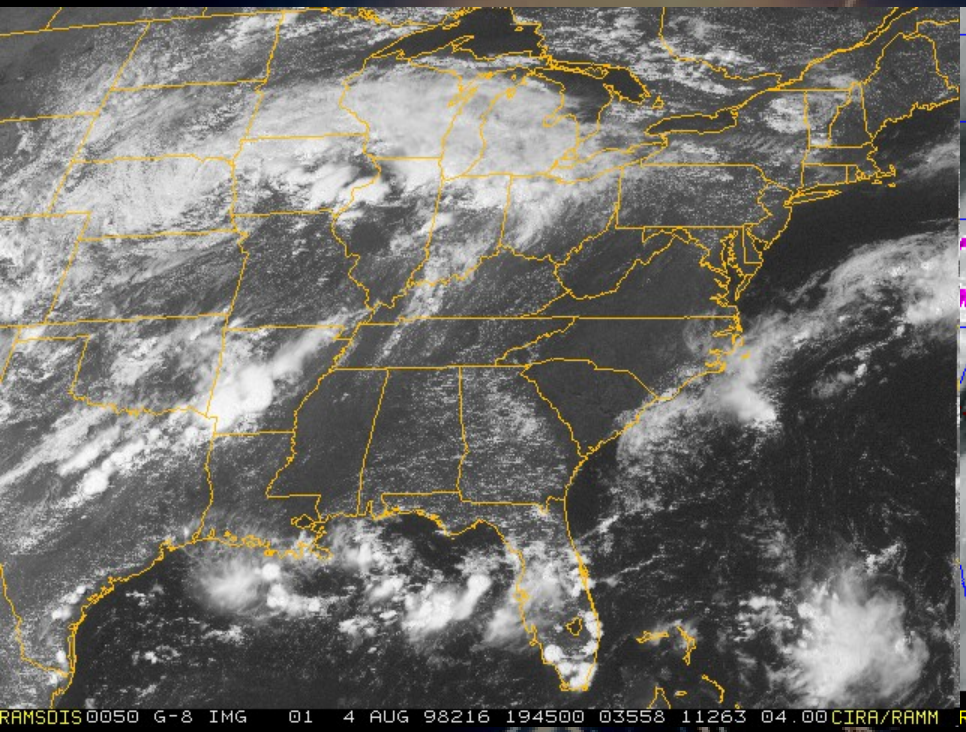
Contamination

- Occurs when energy reaches the sensor from 2 or more sources in the same satellite footprint, corrupting the image.
- The most obvious example is probably thin cirrus. On satellite images you can often see through it to lower clouds or the surface of the ocean.

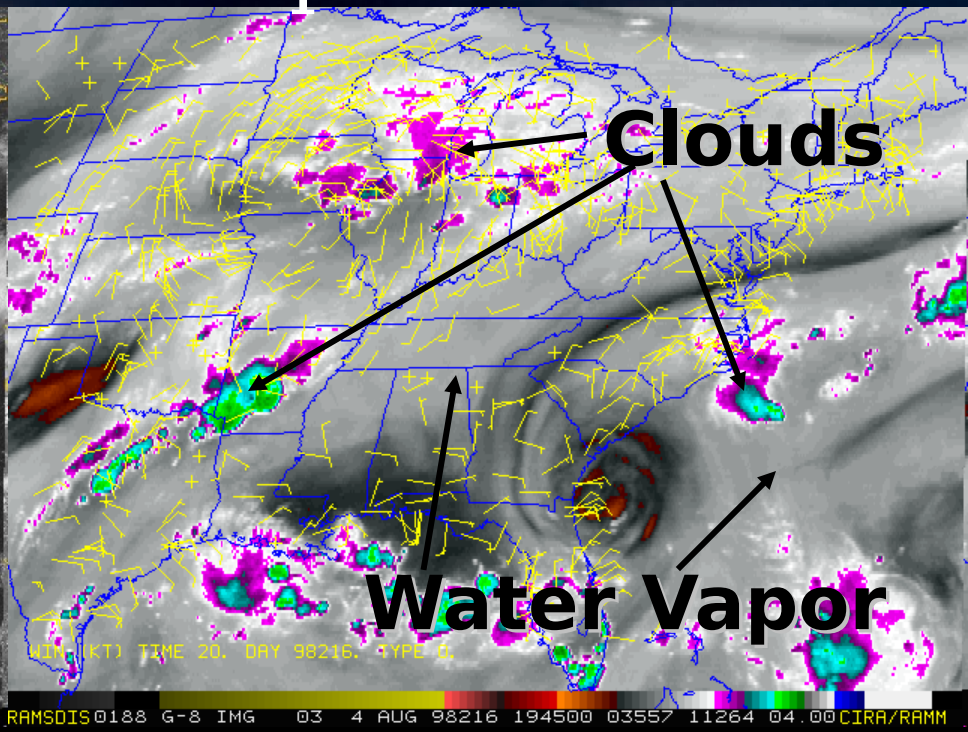
Viewing Considerations

- Contamination - occurs when energy reaches the sat from 2 or more sources. Can occur with VIS or IR imagery
  - –Typical situation for contamination to occur involves a high cloud which is not thick enough to completely block out radiation from another source. Sensor will average the temperature/brightness of the two objects, producing errors in the values for both objects

GOES 8 Visible



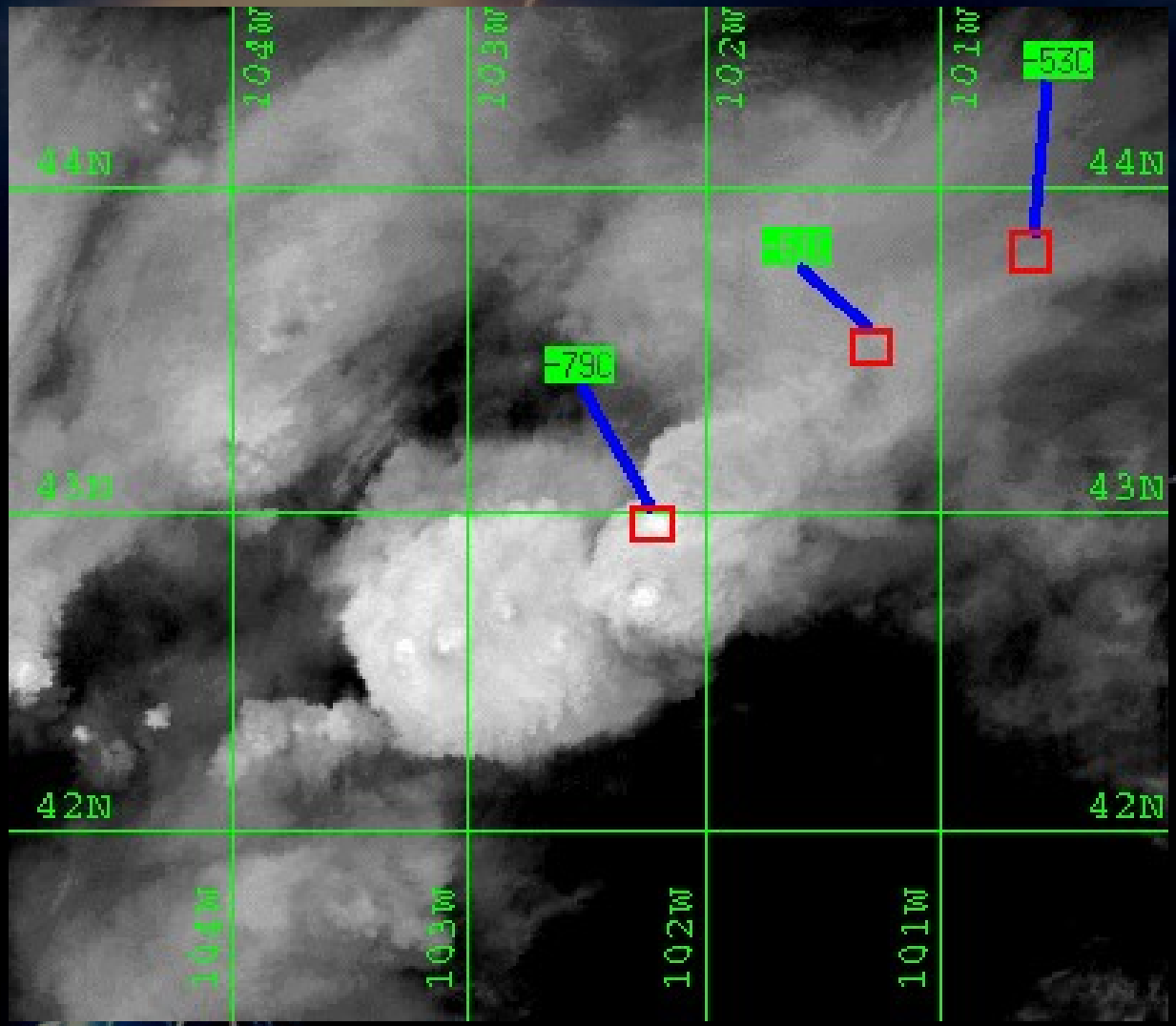
GOES 8 Water Vapor Channel

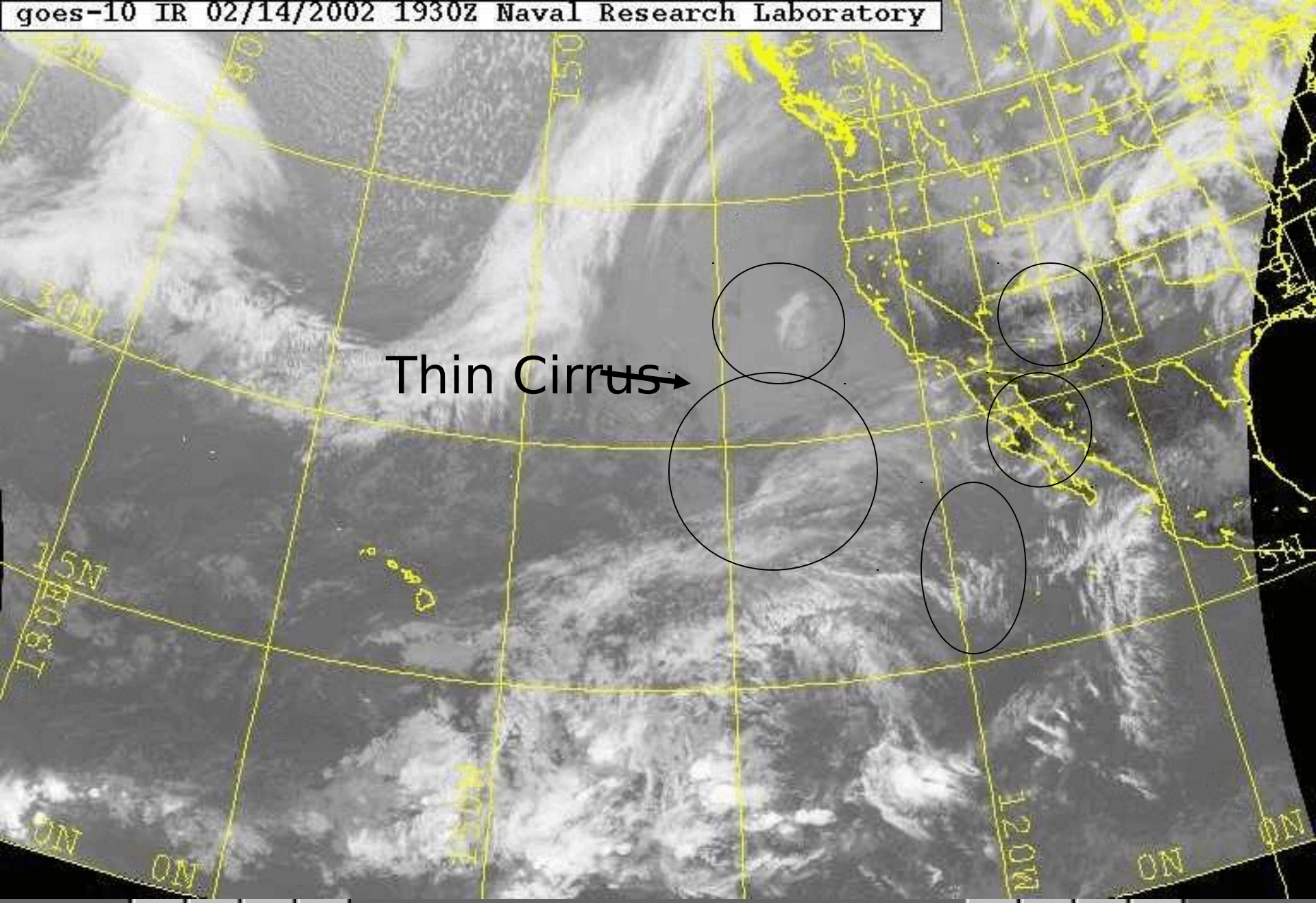


Low H_20 Contamination
Can see the surface

High H_20 Contamination
Can't see the surface

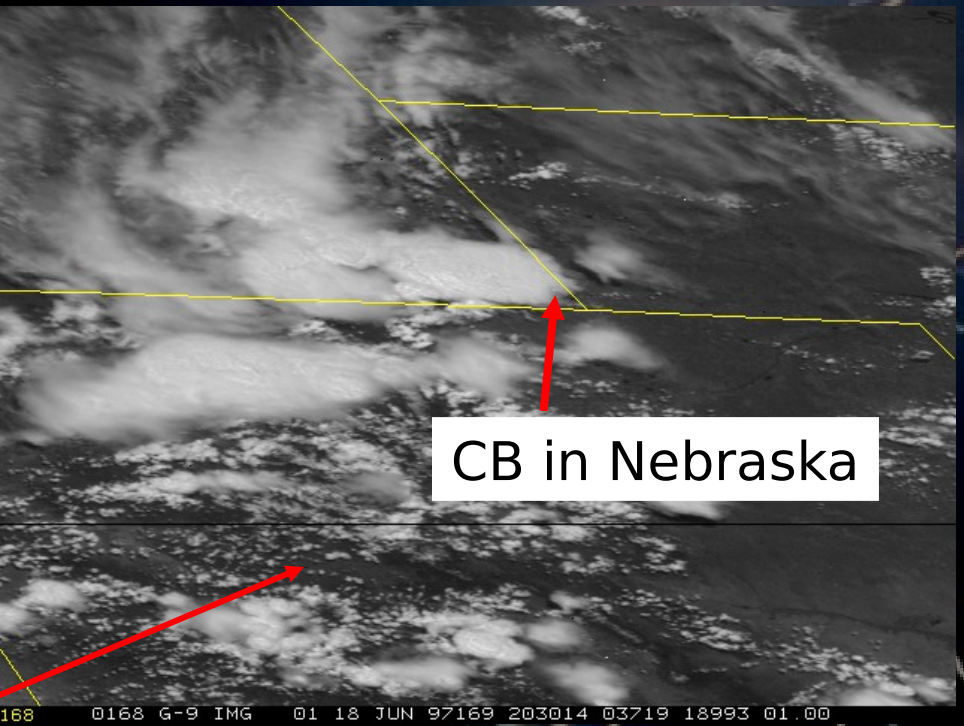
Transmission

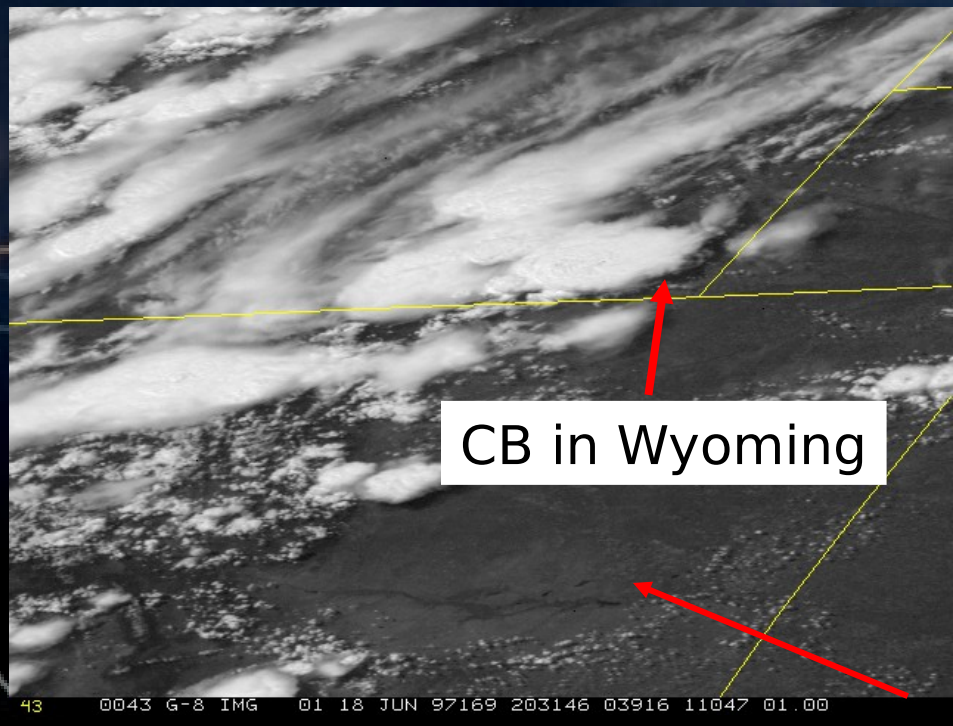



goes-10 IR 02/14/2002 1930Z Naval Research Laboratory
Thin Cirrus

Foreshortening

- Loss of resolution caused by oblique viewing angle resulting in distortion
- Parallax - apparent shift in location of an elevated object when it is viewed from the side

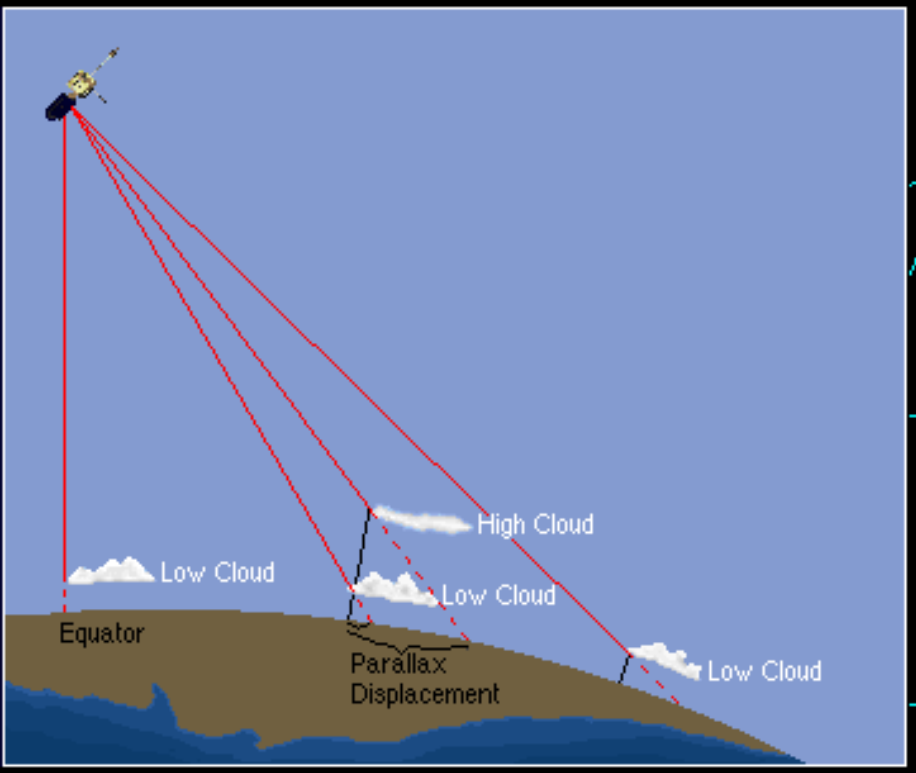




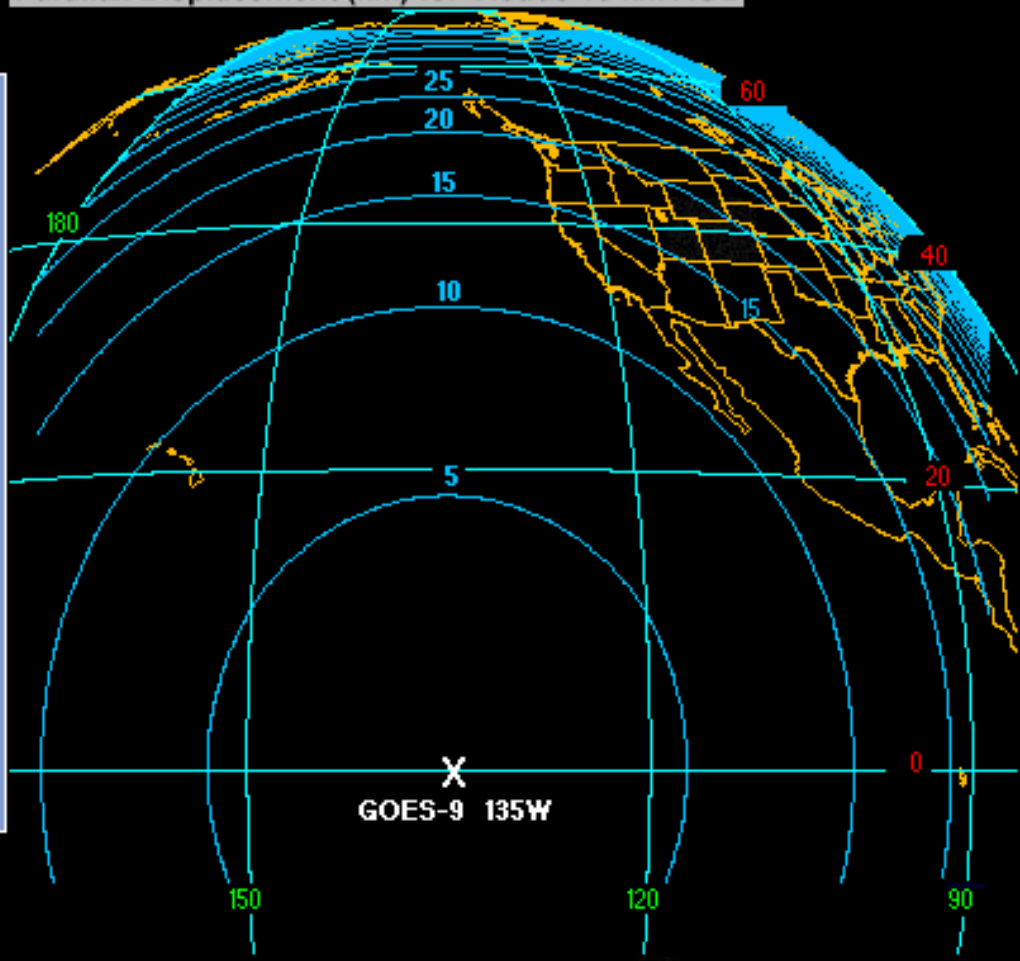
Viewing Vector for G10 Viewing Vector for

Case Study from NOAA-NESDIS Regional Forecast Team

Satellite Parallax



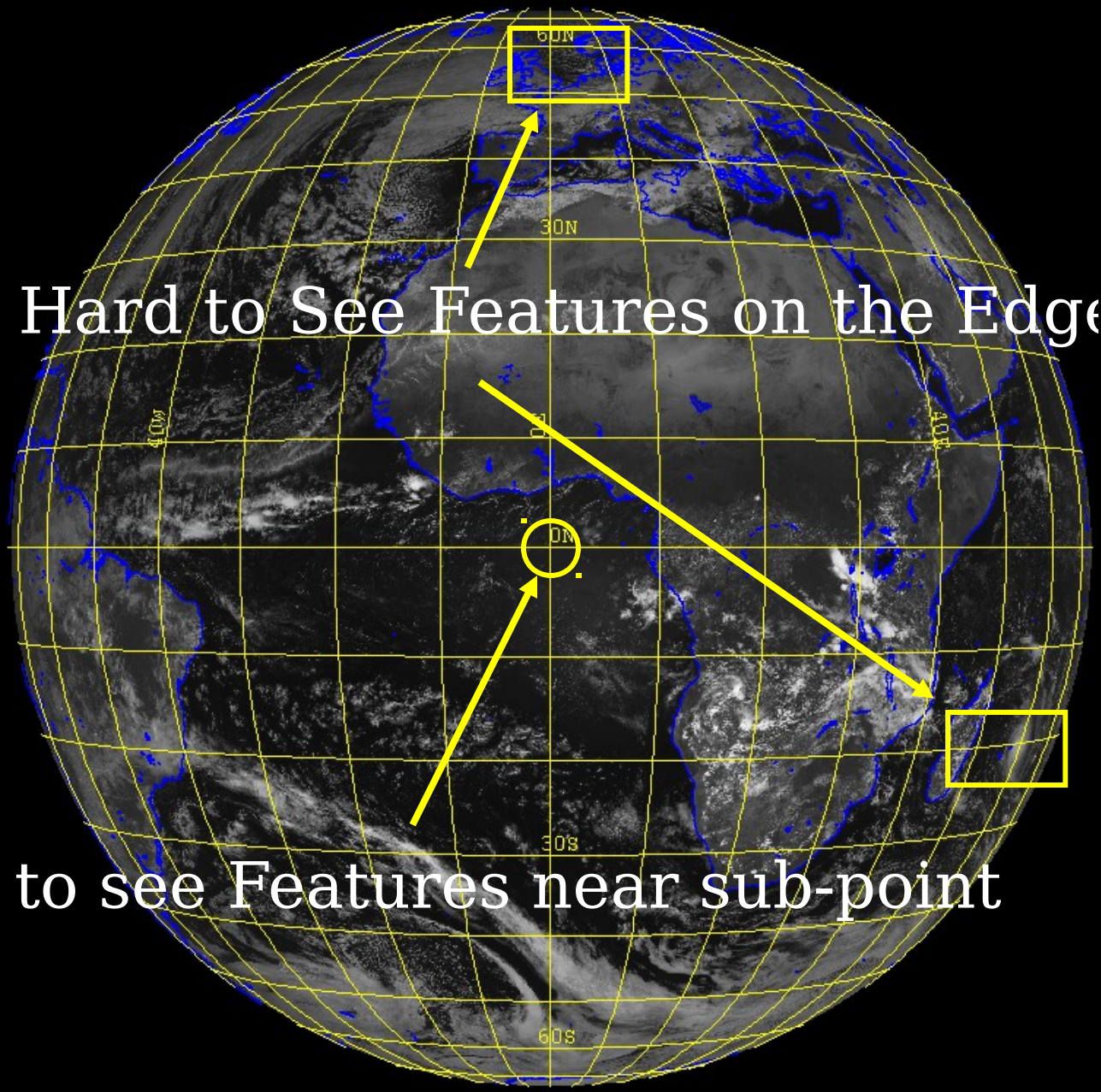
Parallax Displacement (km) for Clouds 13 km AGL



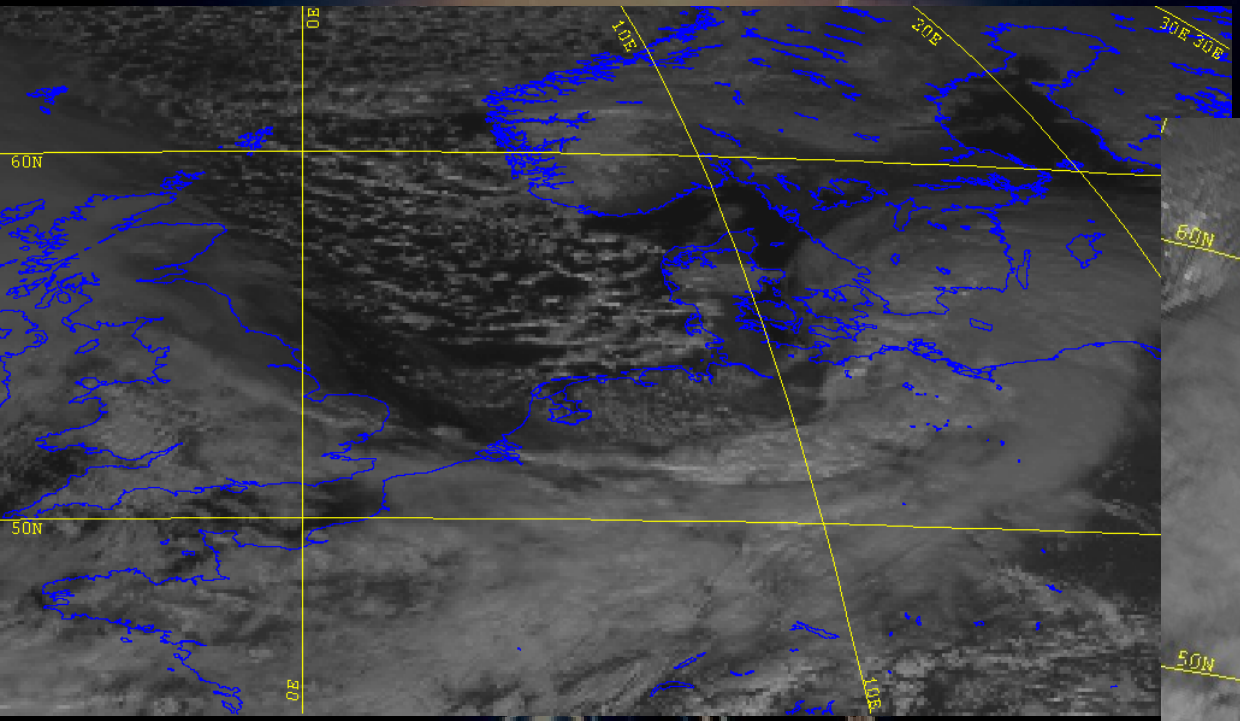
The COMET Program

Imaging Tools

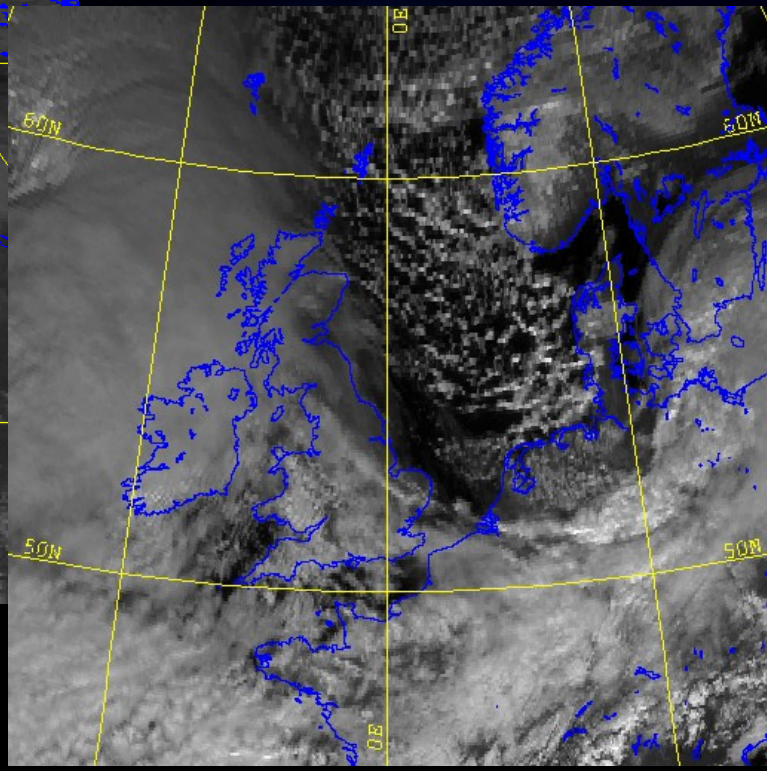
- Projection-Zooming
- Enhancement
- Scaling--Color
- Multi-spectral
- Overlays


60N
30N
0N
30S
60S
40W
40E
Hard to See Features on the Edge
Easy to see Features near sub-point

Easier to view areas away from sub-point if you Zoom or Re-project

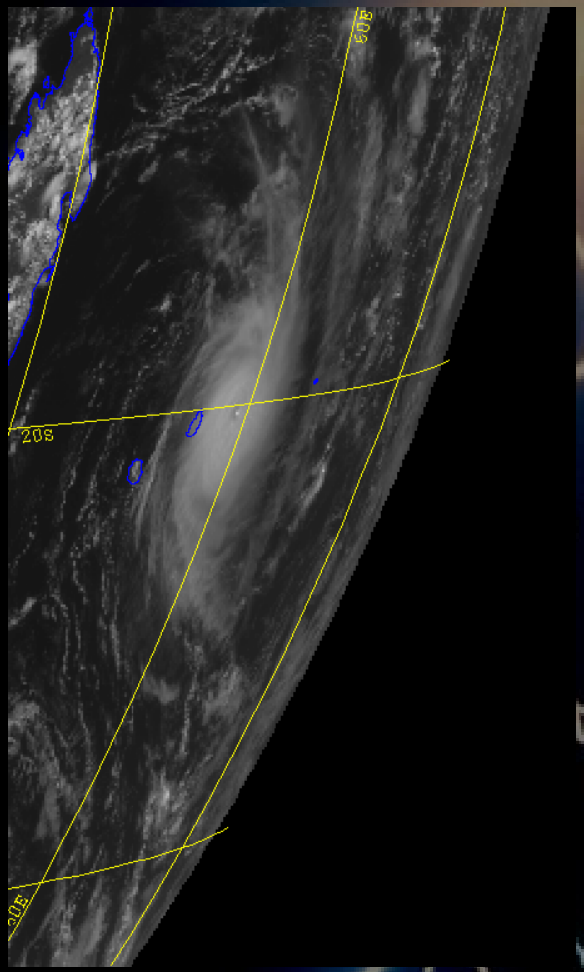


Zoom, Notice Flattening

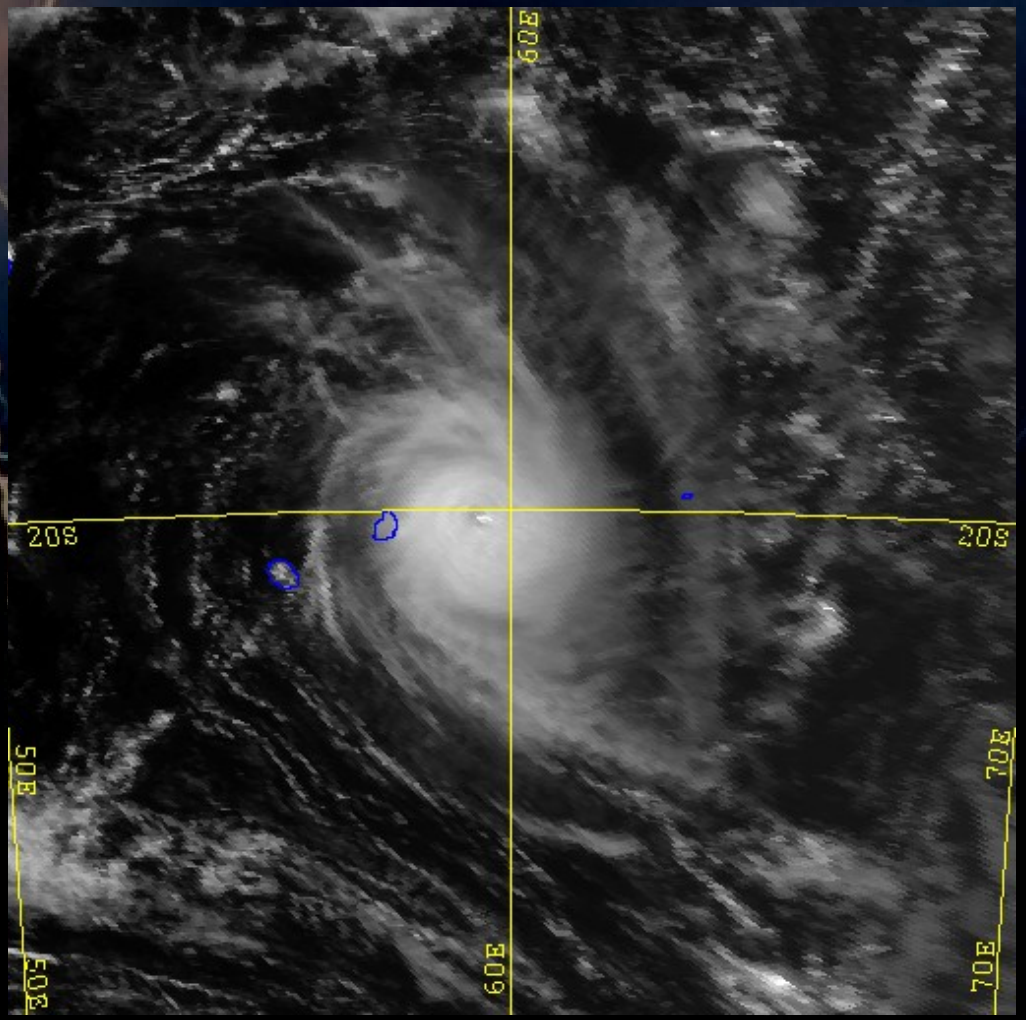


Re-projection, less Distortion

Zoom or Re-project to see Tropical Cyclone at E



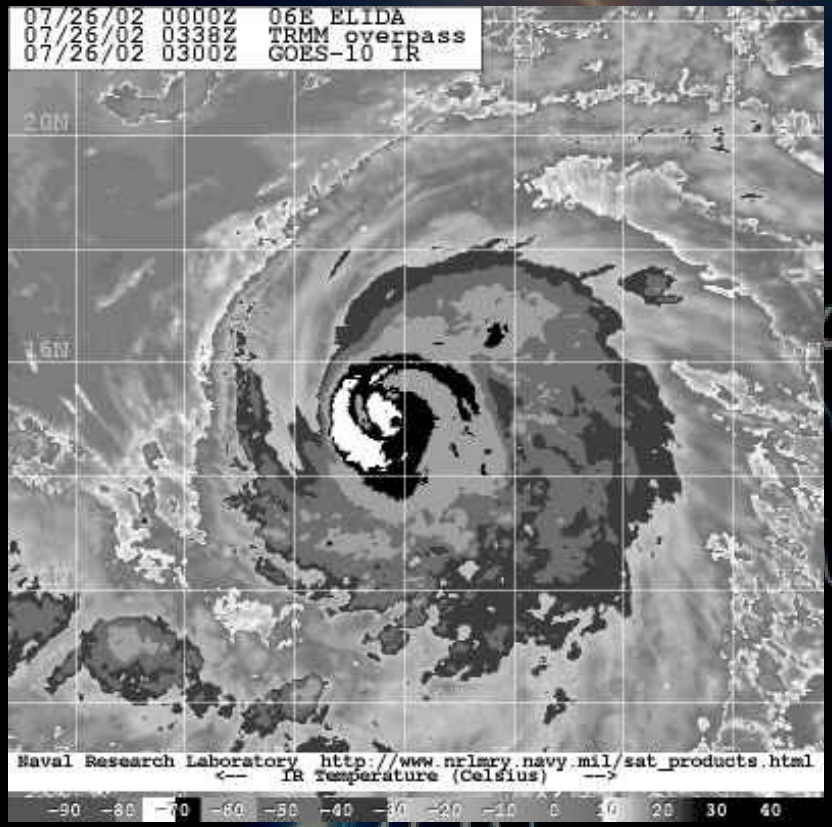
Distortion at Edge



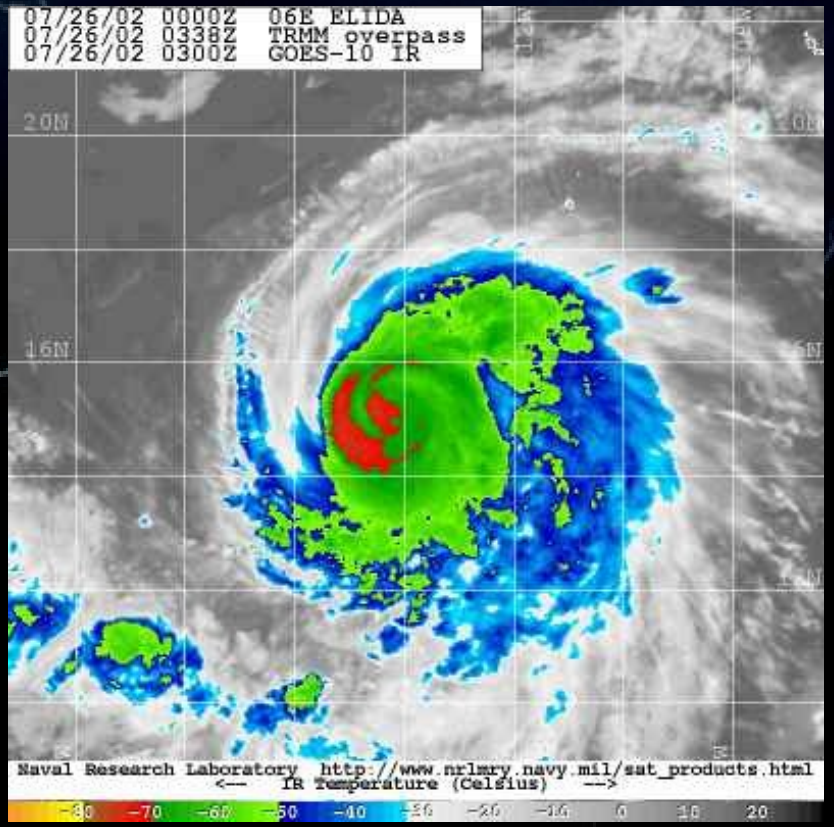
Re-projection to Correct Distort

IR Enhancement

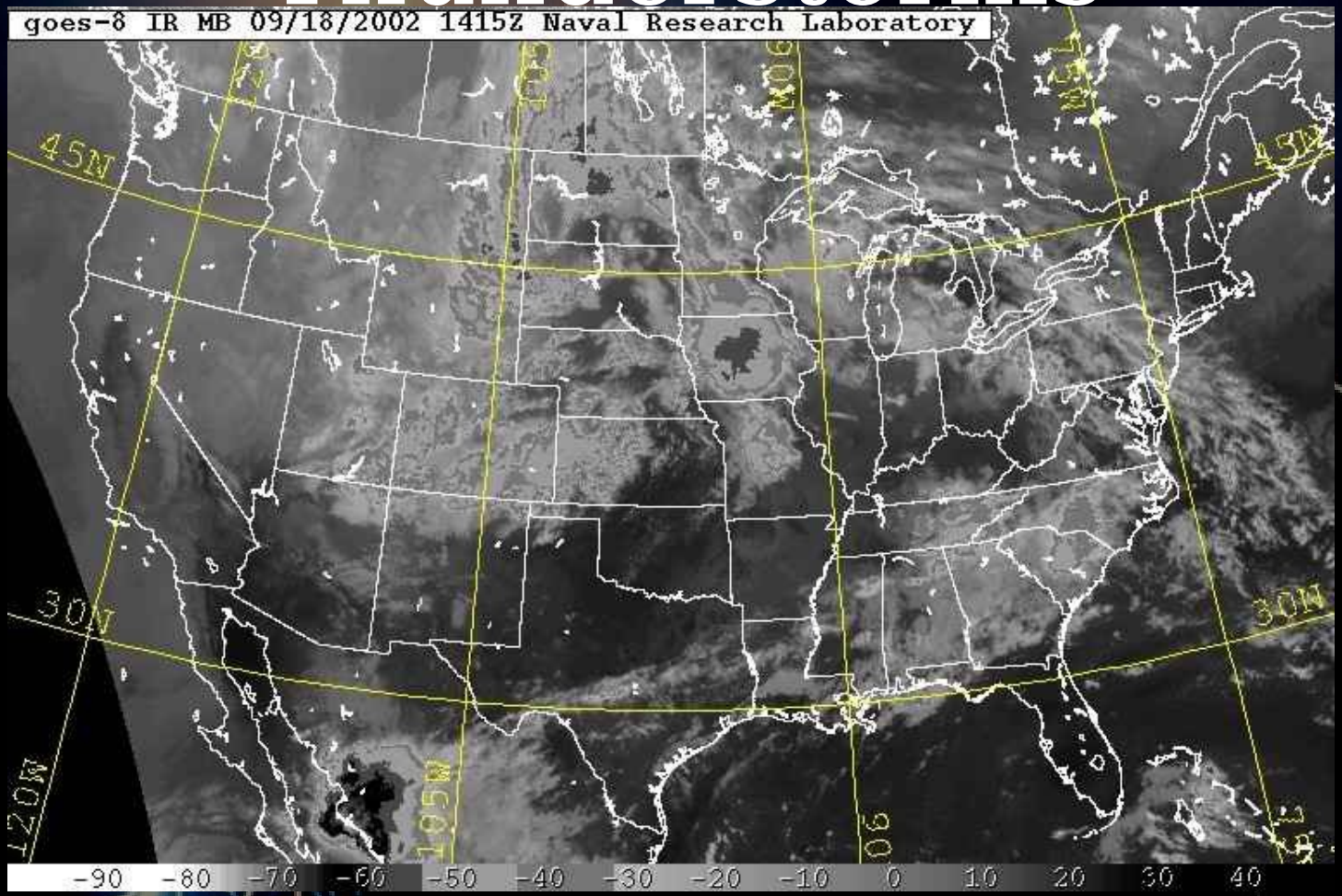
IR – BD Enhancement



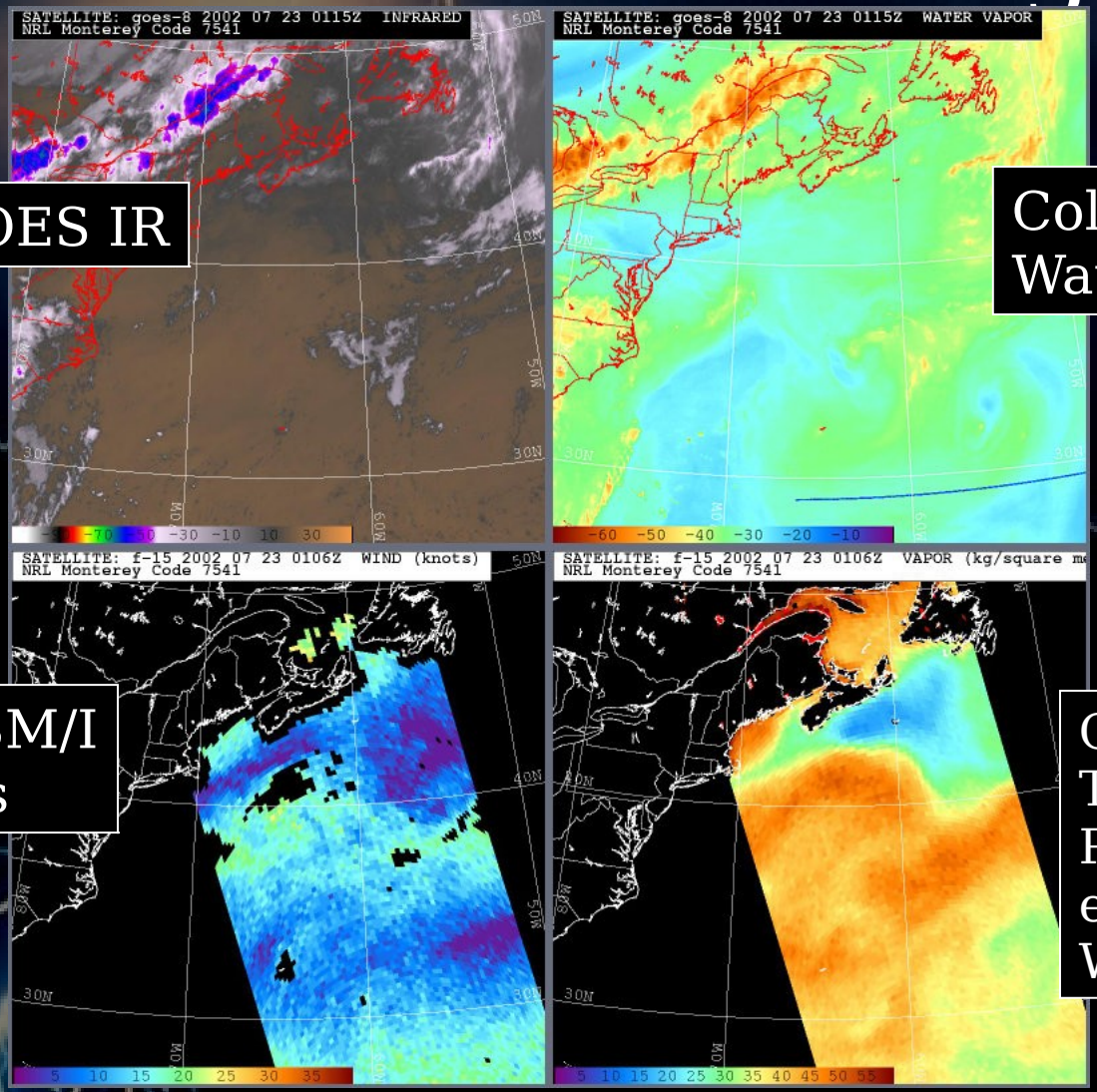
IR – Color



MB Enhancement (IR) Thunderstorms



Color and Scaling


SATELLITE: goes-8 2002 07 23 0115Z INFRARED
NRL Monterey Code 7541
SATELLITE: goes-8 2002 07 23 0115Z WATER VAPOR
NRL Monterey Code 7541
SATELLITE: f-15 2002 07 23 0106Z WIND (knots)
NRL Monterey Code 7541
SATELLITE: f-15 2002 07 23 0106Z VAPOR (kg/square m
NRL Monterey Code 7541

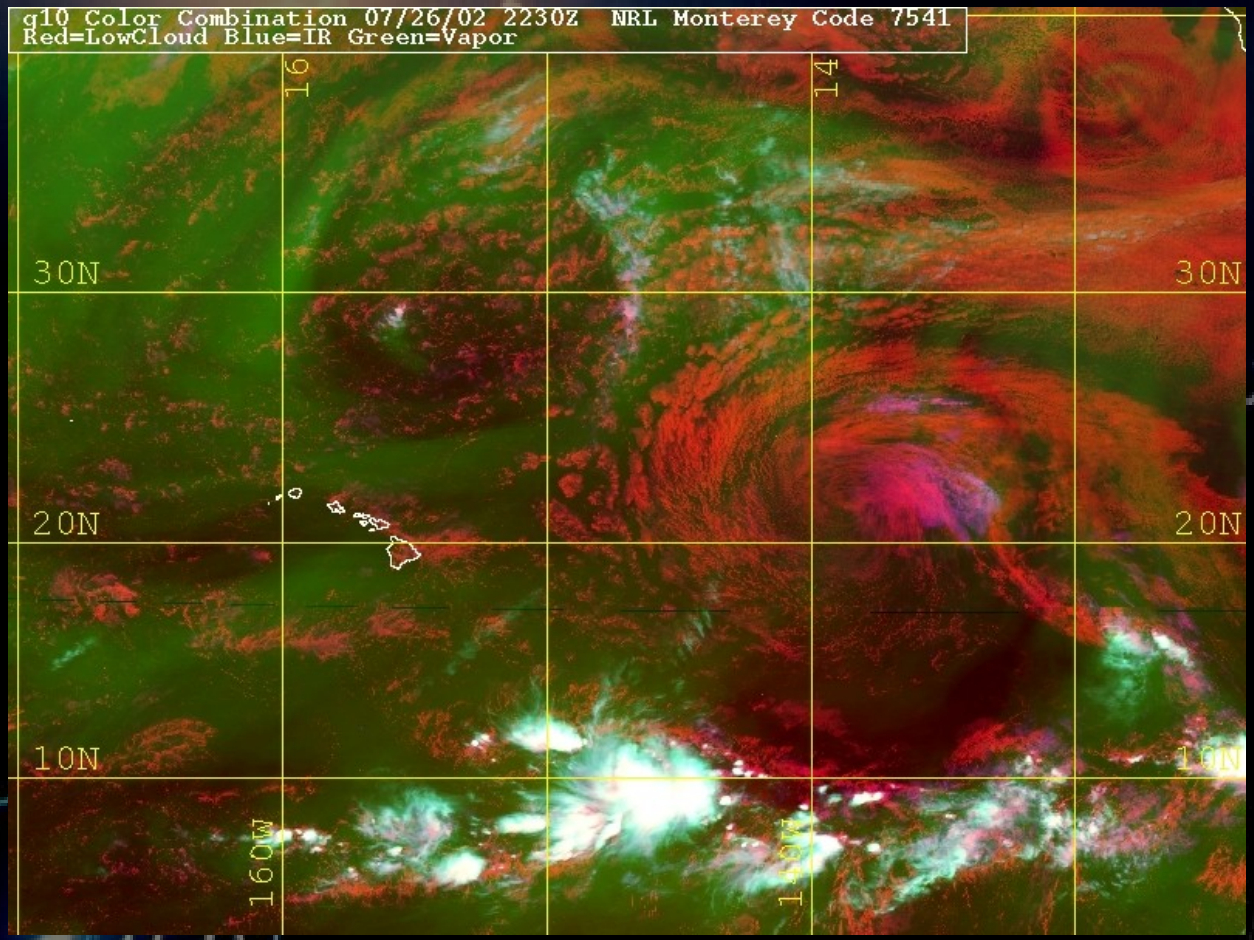
Colorized GOES IR

Colorized GOES Water Vapor

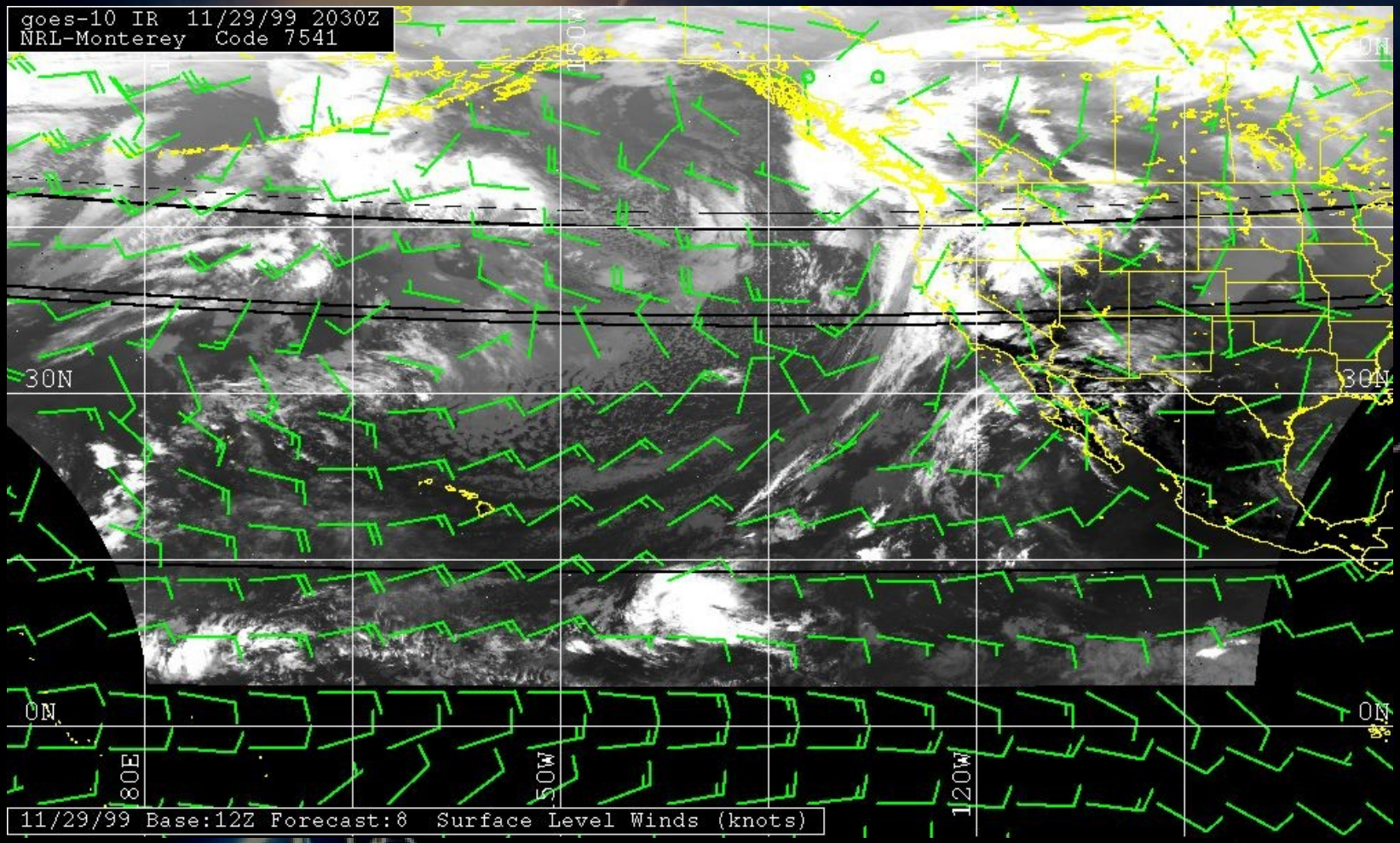
Colorized SSM/I Wind Speeds

Colorized Total Precipitable Water

Multi-spectral

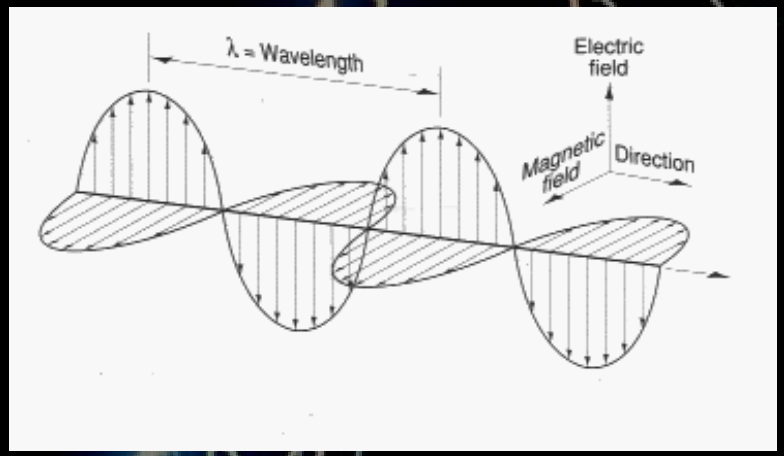


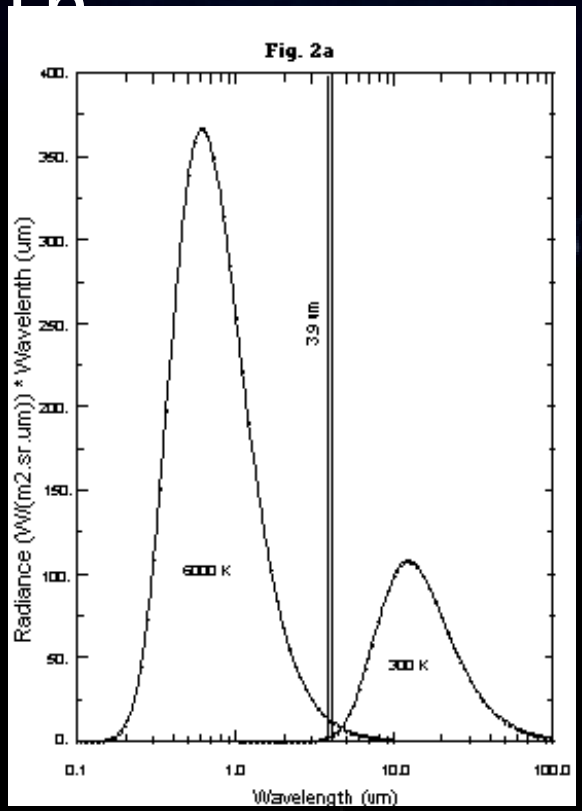
Overlays


goes-10 IR 11/29/99 2030Z
NRL-Monterey Code 7541
30N
0N
80E
50W
120W
11/29/99 Base:12Z Forecast:8 Surface Level Winds (knots)

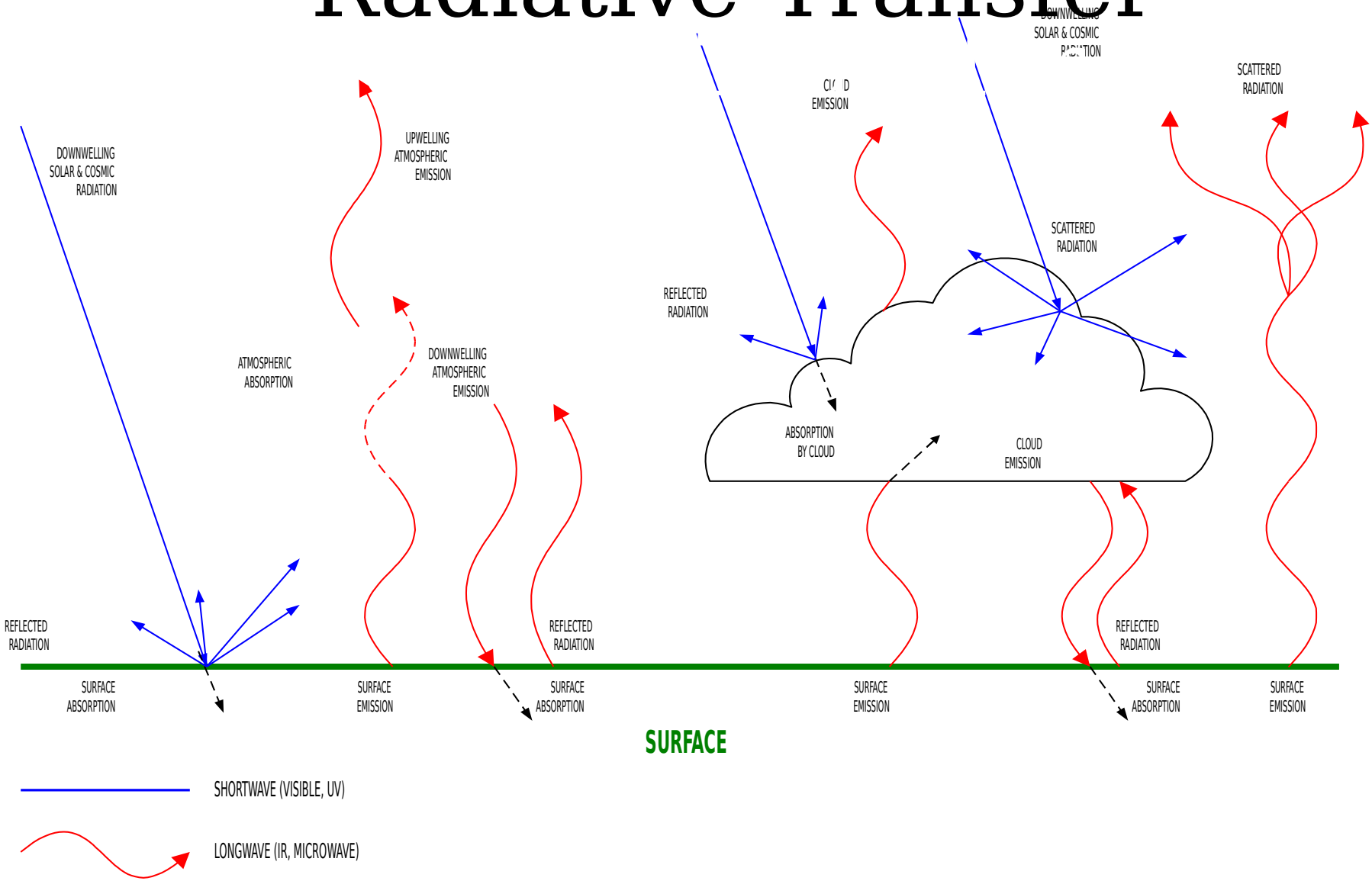
Advanced Satellite Theory

- Frequency & Wavelength
- Planck's Law
- Kirchoff's Law

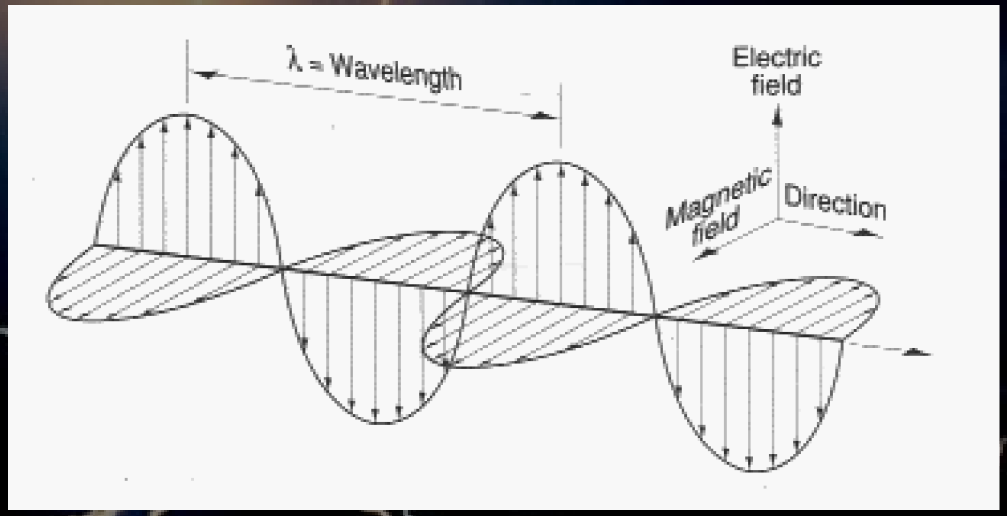




Radiative Transfer



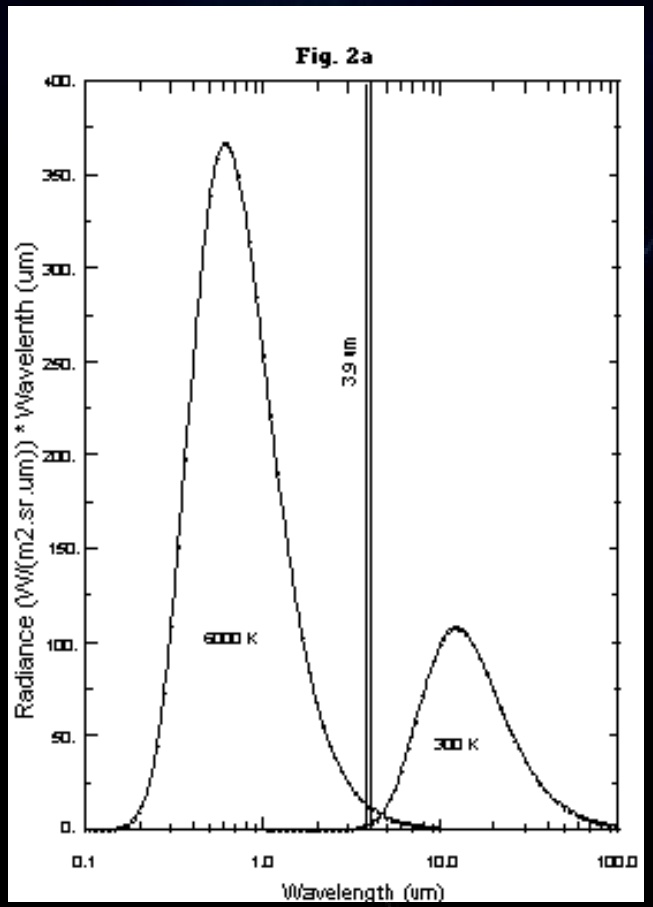
Wavelength & Frequency



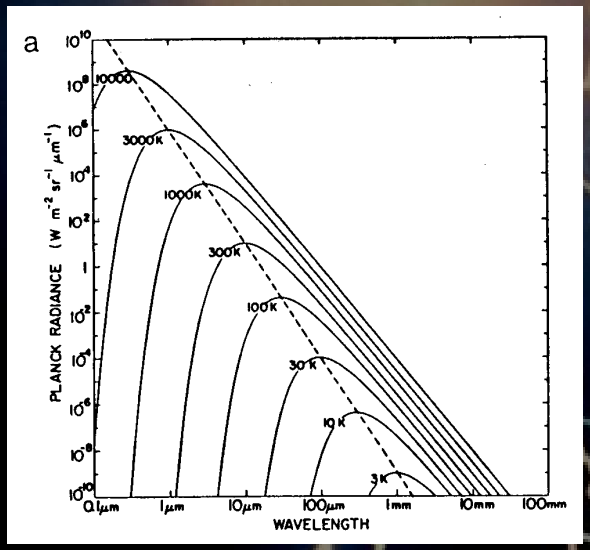
- Oscillating waves
- Shorter wavelength, higher frequency
- Longer wavelength, lower frequency
- Vertical (electric) and horizontal (magnetic) components

Planck's Law

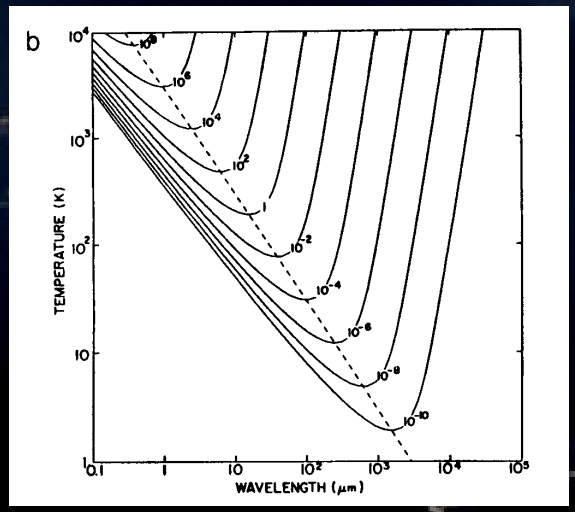
- The hotter an object, the more radiation it produces.
- The temperature of the body determines the quantity and frequency of radiation produced by an object.



Planck Function



Radiance vs. wavelength for indicated Temperature



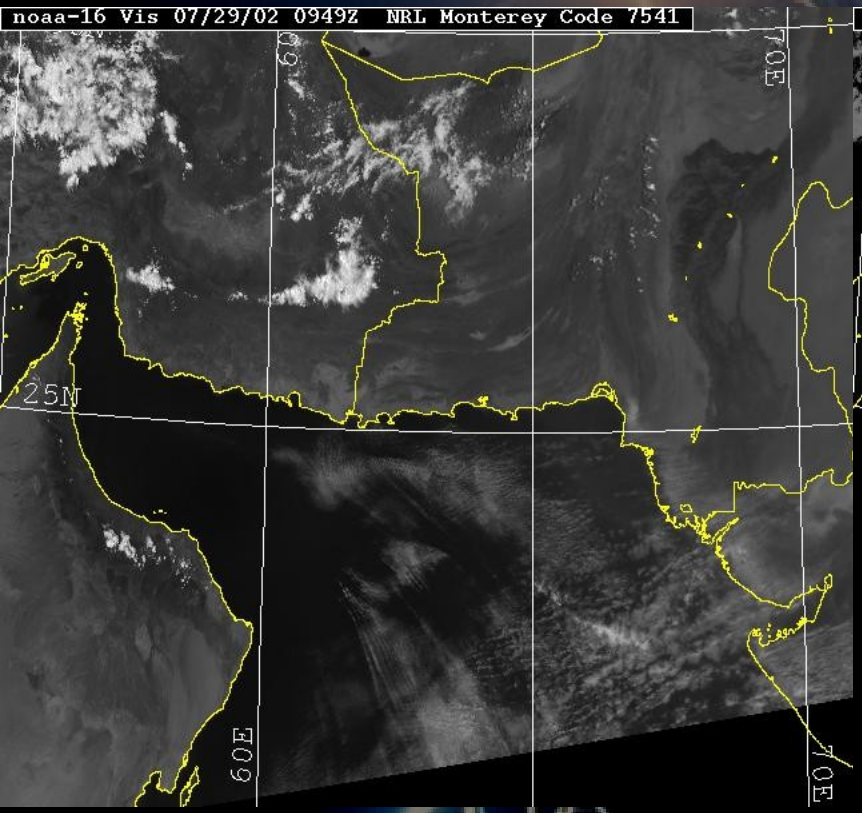
Temperature vs. wavelength for indicated radiance

- The total area under the curve increases with increasing temperature
- **The warmer the source, the more energy it gives off**
- Describes the emission of a surface or body as a function of wavelength and temperature
- A unique value for each wavelength and temperature

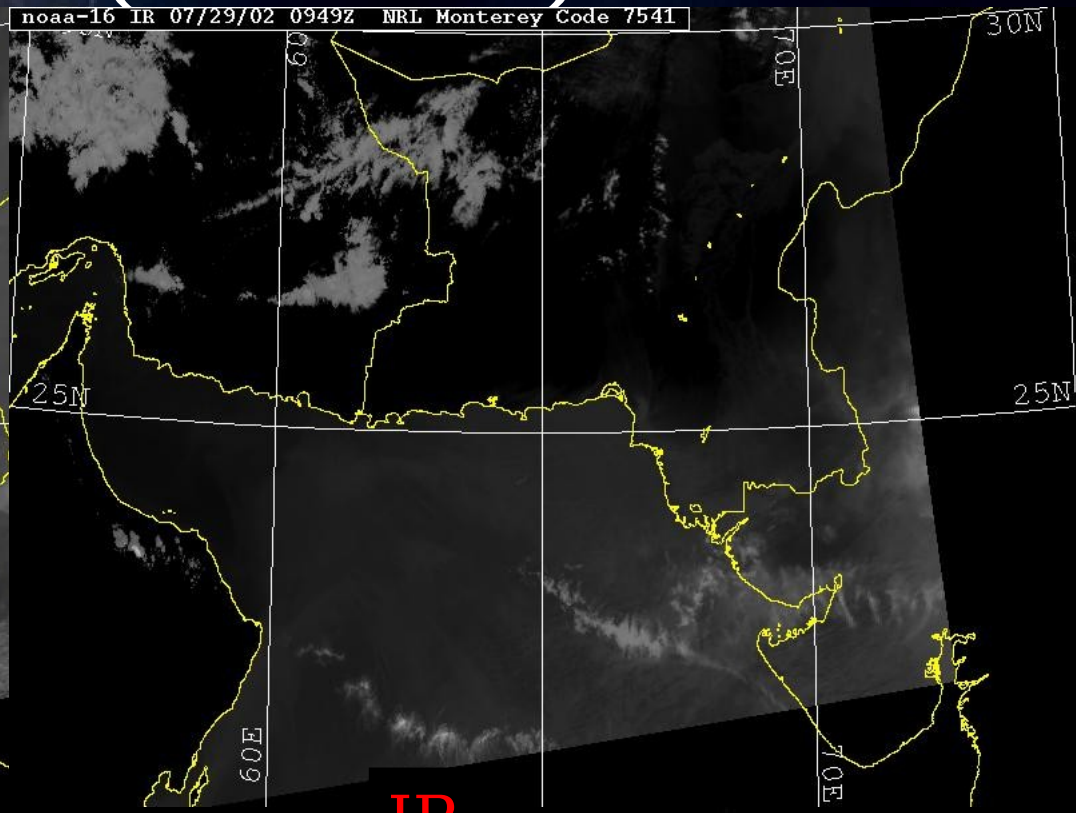
Visible and Infrared Interpretation

- Visible Images
- Infrared Images
- Cloud Typing

Brightness Temperature (IR) Albedo (Visible)



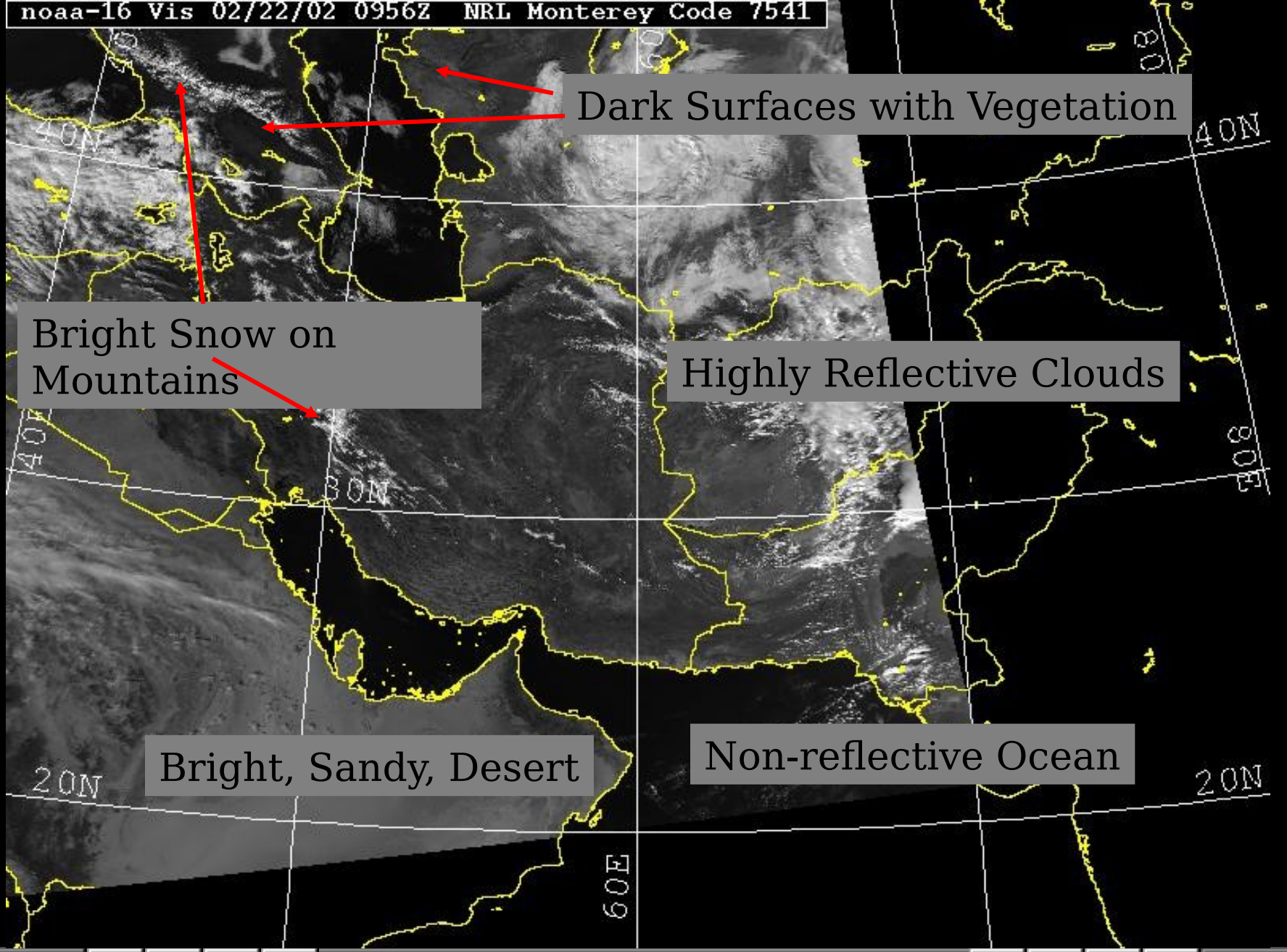
Visible

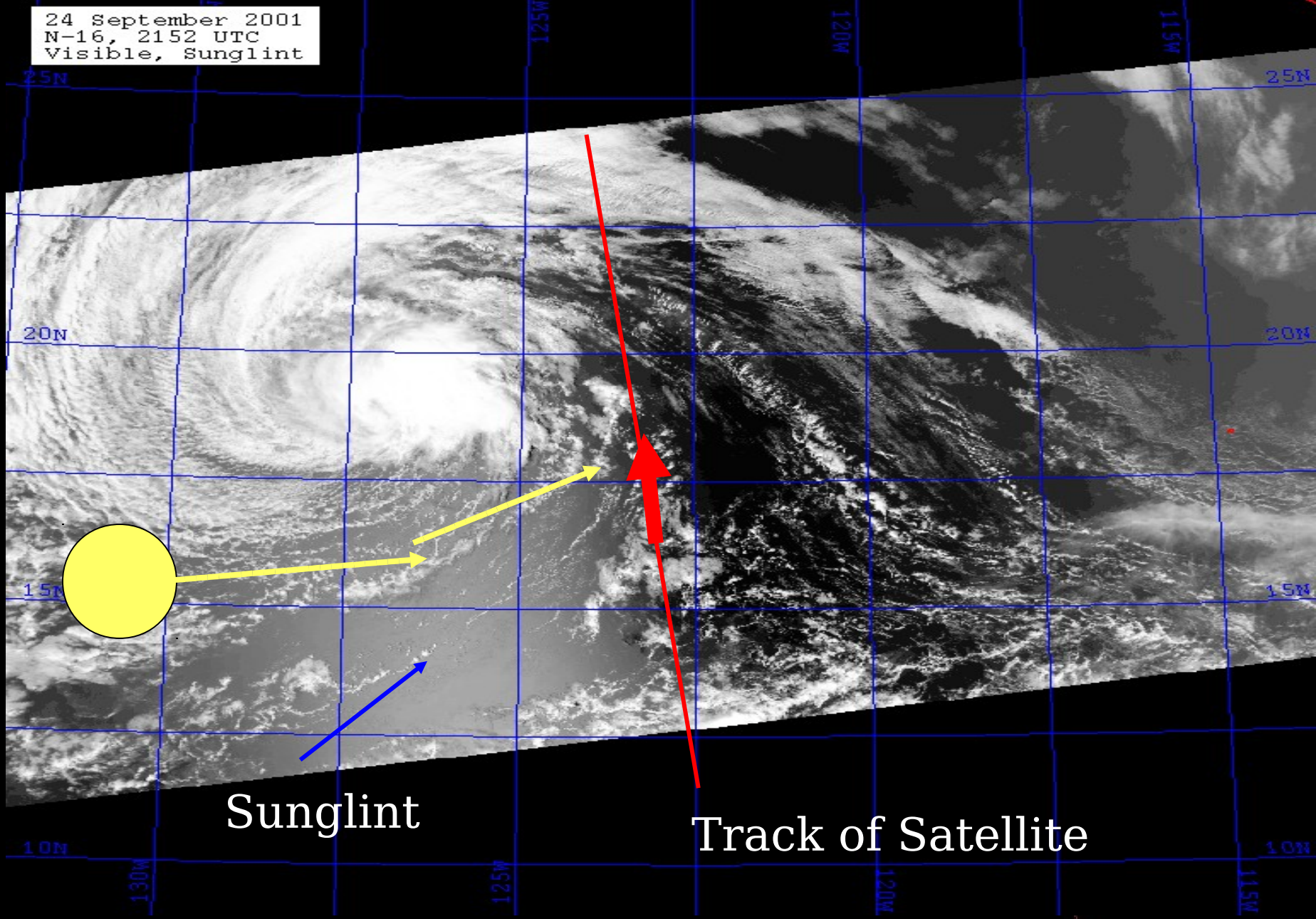


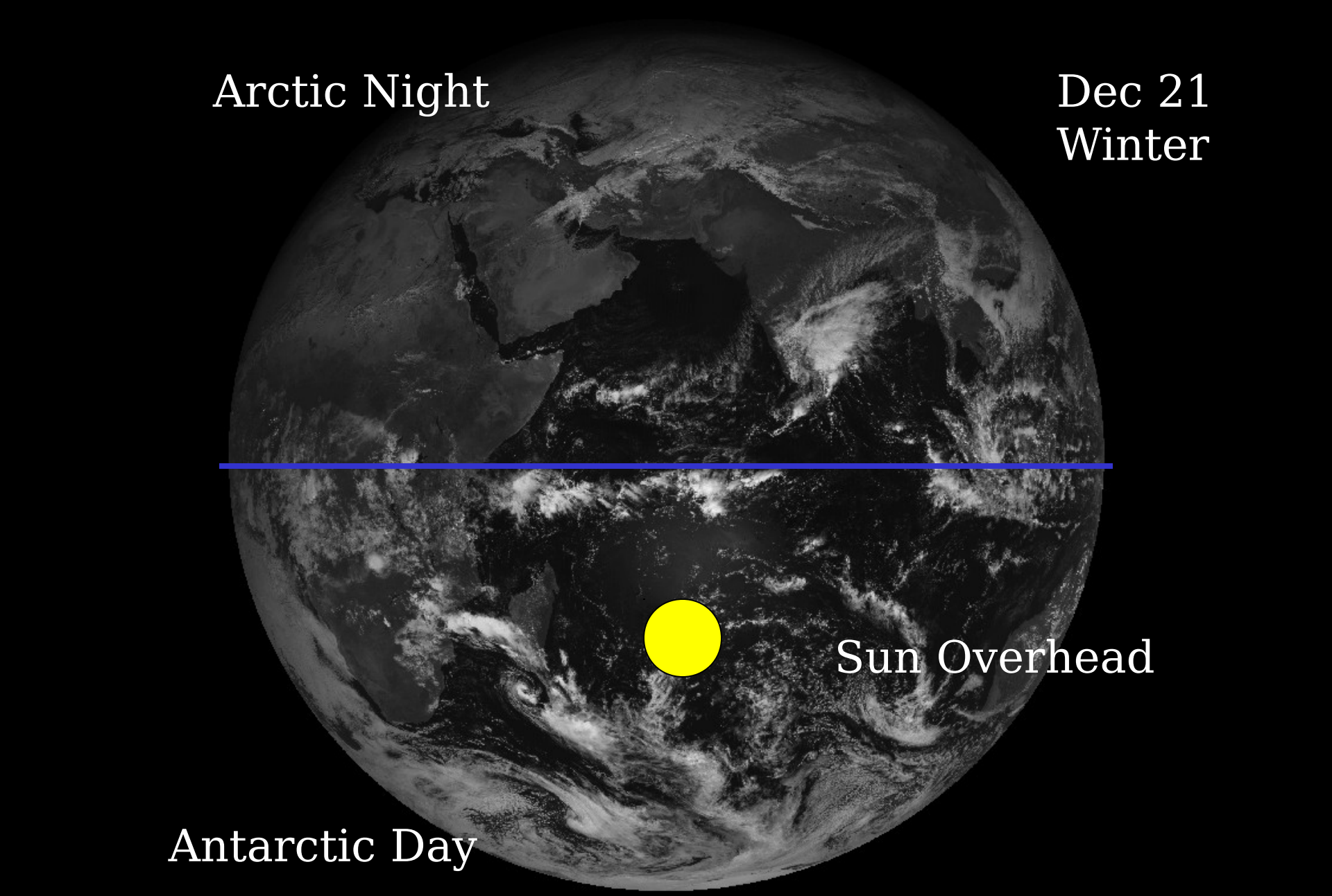
IR

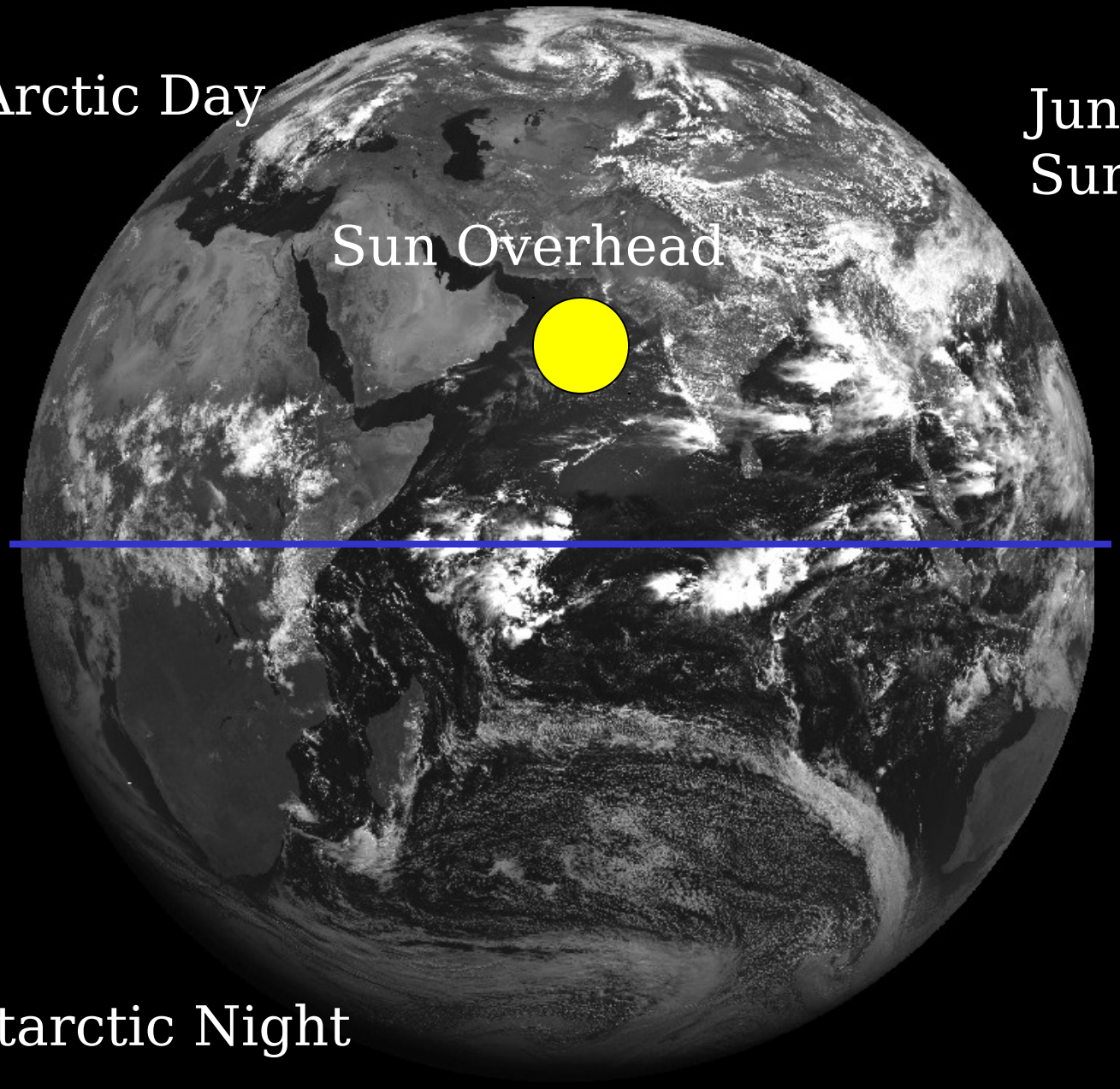
Visible Images

- Generally have highest spatial resolutions of all kinds of imagery (~ 1 km). Great images!
- Daytime only, except for DMSP nighttime visible.
- Good for seeing low clouds, land features, smoke, and land/water contrast.
- Different cloud types often look identical (unlike IR).
- Appearance varies tremendously by time of day and time of year.
- Corresponds to what we would see if we were astronauts looking out the window at the earth.


noaa-16 Vis 02/22/02 0956Z NRL Monterey Code 7541
Dark Surfaces with Vegetation
Bright Snow on Mountains
Highly Reflective Clouds
Bright, Sandy, Desert
Non-reflective Ocean
40N
30N
20N
60E


24 September 2001
N-16, 2152 UTC
Visible, Sunglint
25N
20N
15N
10N
130W
125W
120W
115W
Sunglint
Track of Satellite


Arctic Night
Dec 21
Winter
Sun Overhead
Antarctic Day

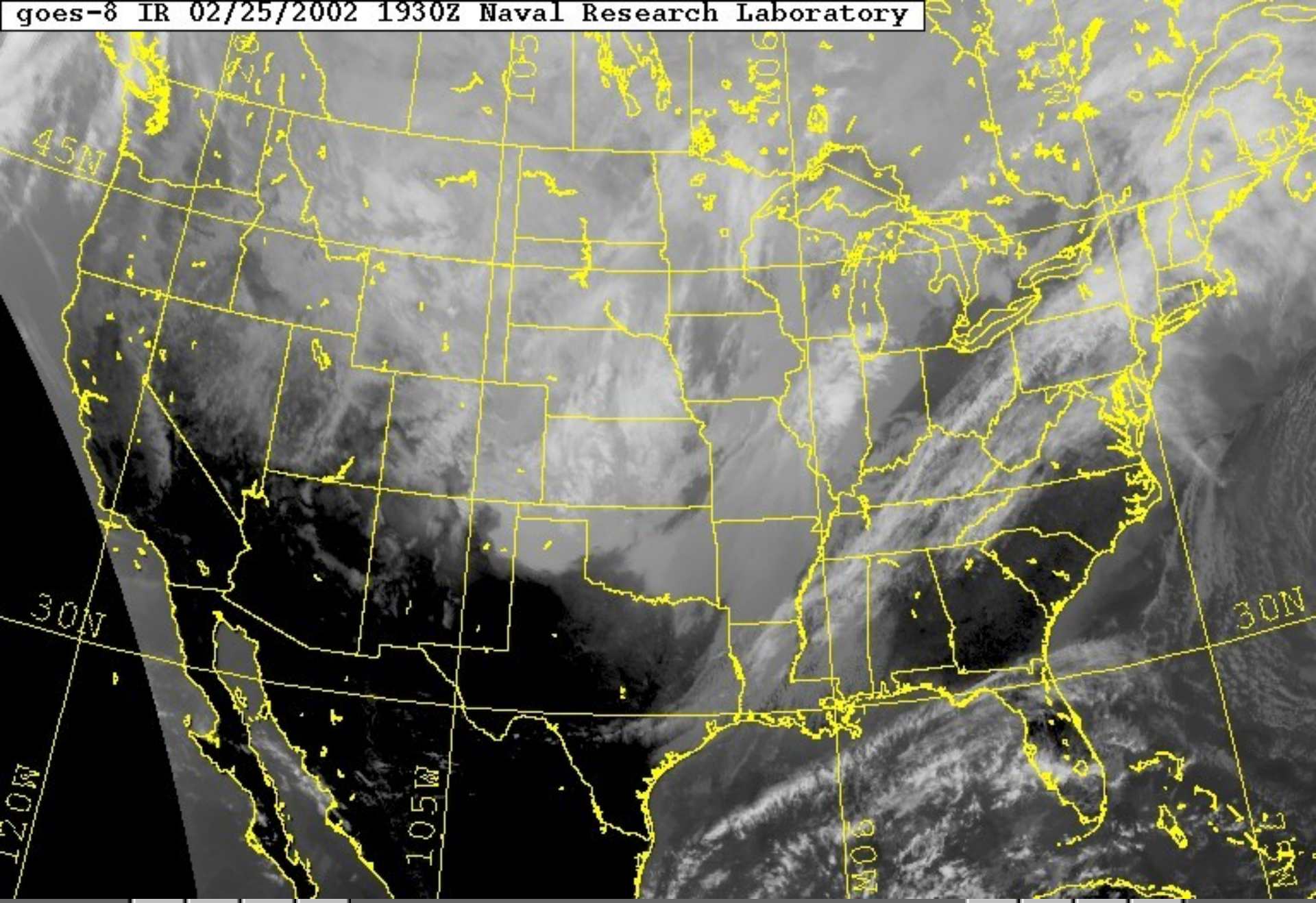

Arctic Day
June 21
Summer
Sun Overhead
Antarctic Night

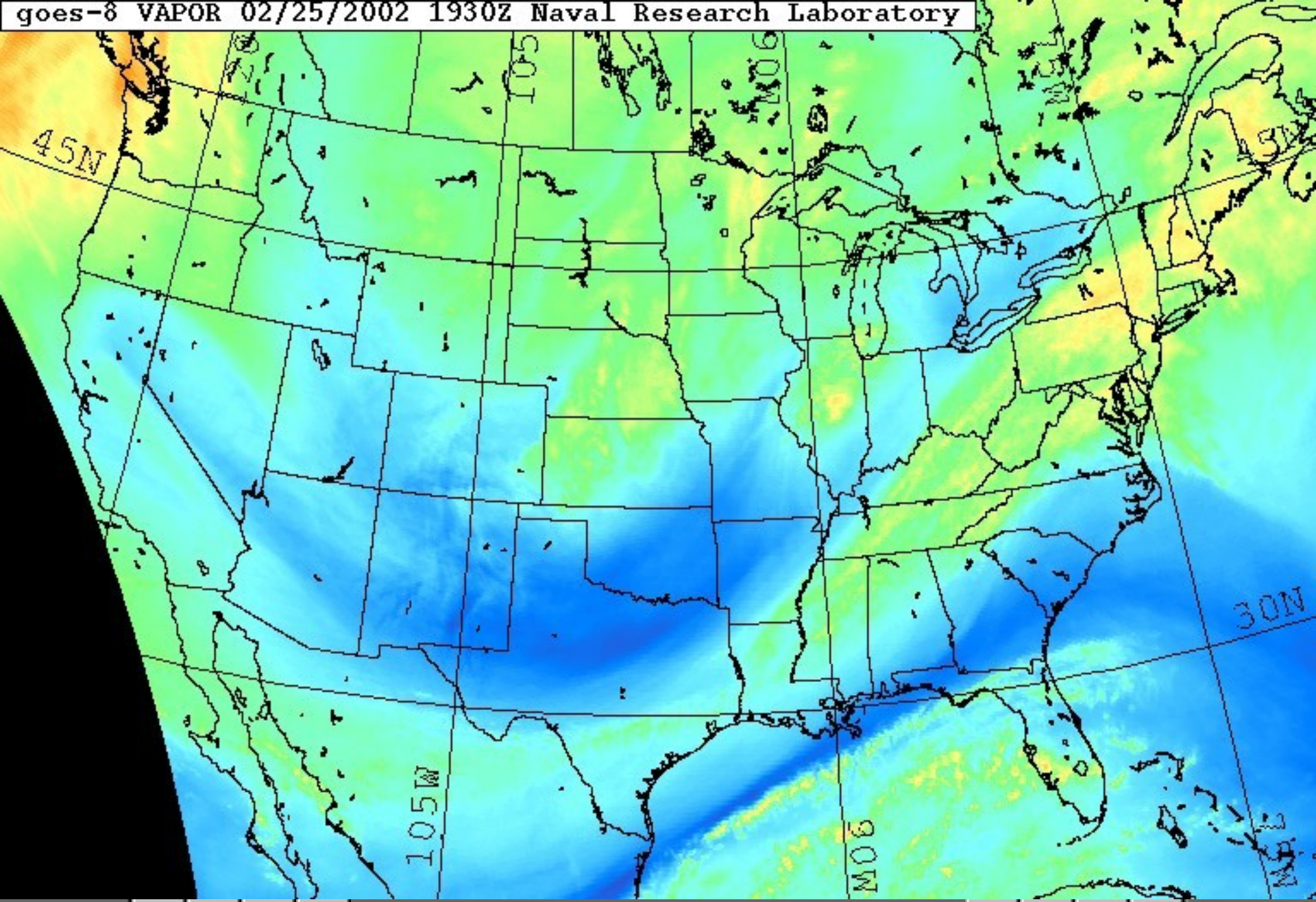
Interpreting Infrared Images

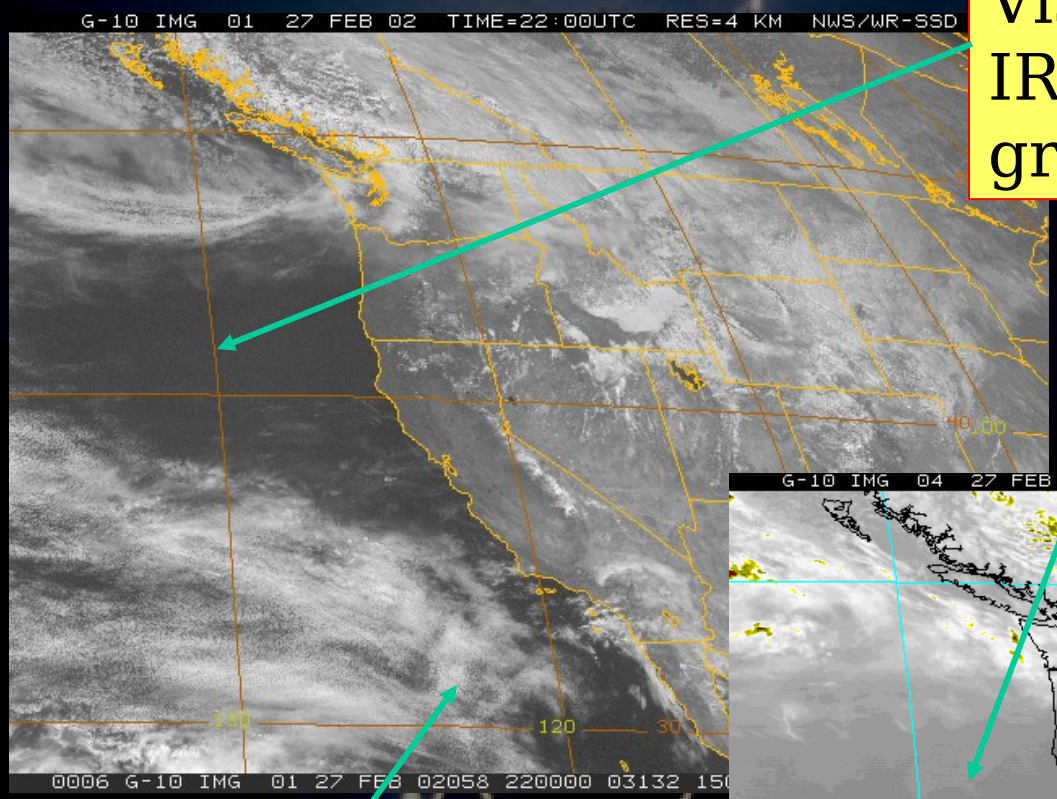
- 24/7 Availability – all times of the year at all latitudes
- Cloud top height information
- Wonderful tracer of cloud/vapor motion
- Hard to see low clouds and fog

Infrared Spectral Regions

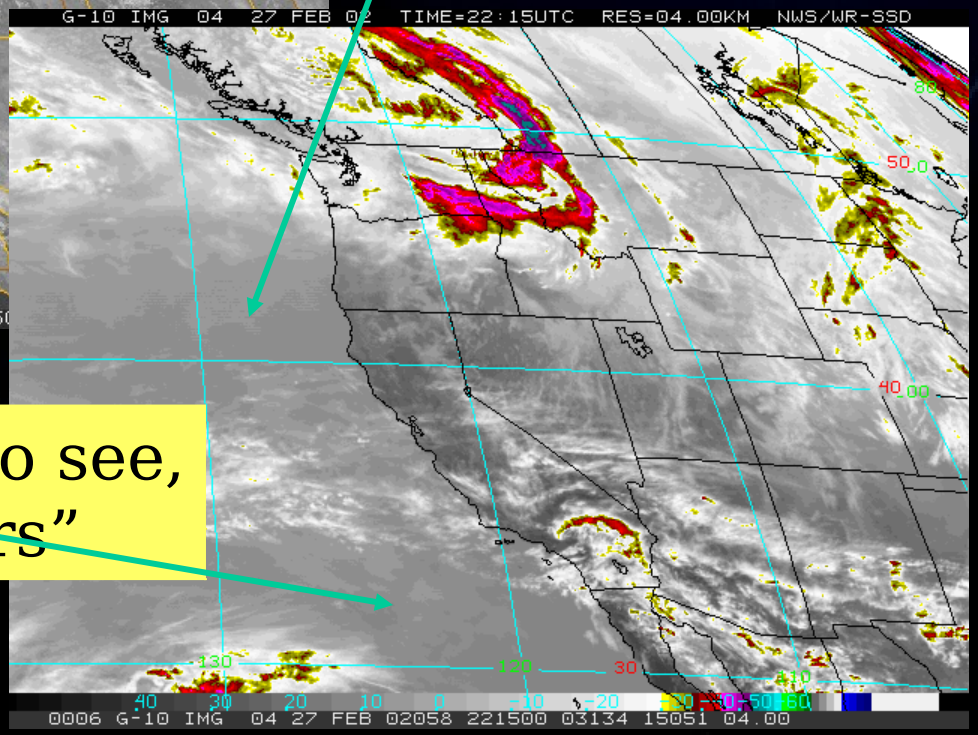
- 11-12 micron – “Garden Variety” IR
- 6.7 micron – Water Vapor Image
- 3.9 micron – Low clouds, hotspots, icing
- Other Regions – Atmospheric Sounding


goes-8 IR 02/25/2002 1930Z Naval Research Laboratory
45N
30N
120W
105W
90W
75W


goes-8 VAPOR 02/25/2002 1930Z Naval Research Laboratory
45N
105
90W
30N
105W
90W



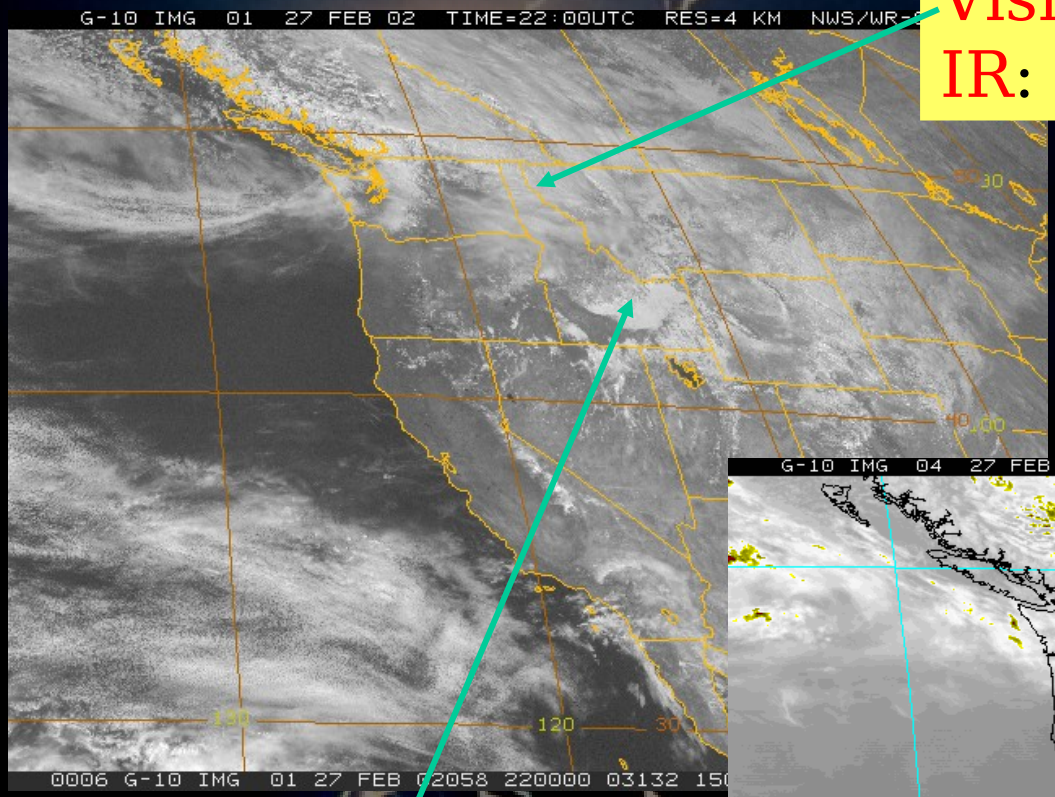
Visible: Ocean Dark,
IR: Ocean “in-between gray-shade”



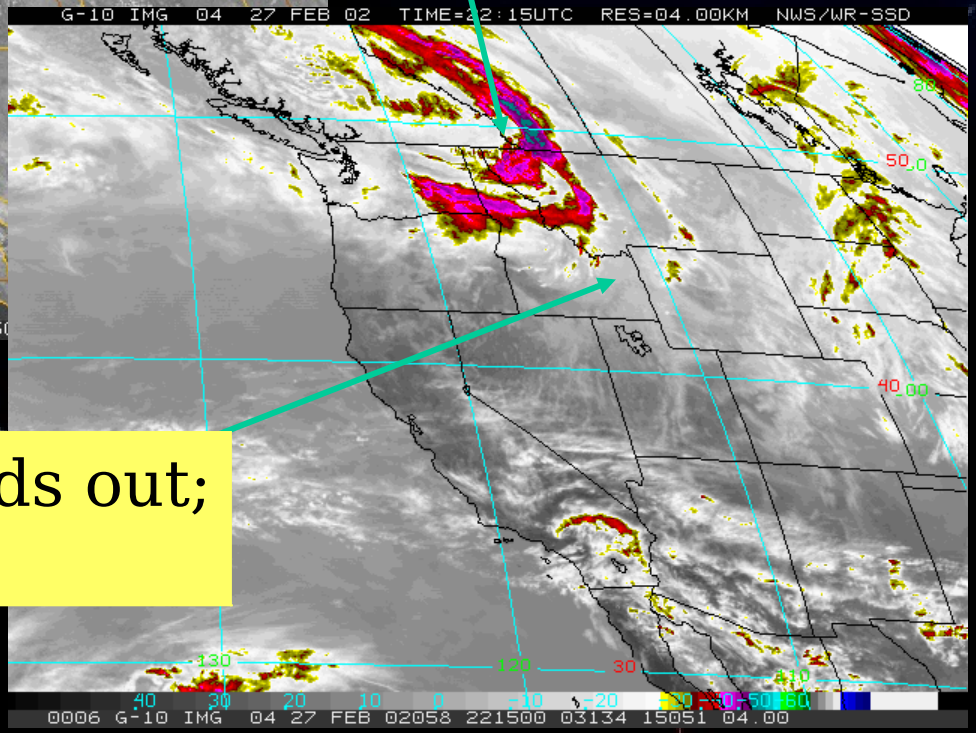
Visible: Stratus easy to see,
IR: Stratus “disappears”

GOES Visible

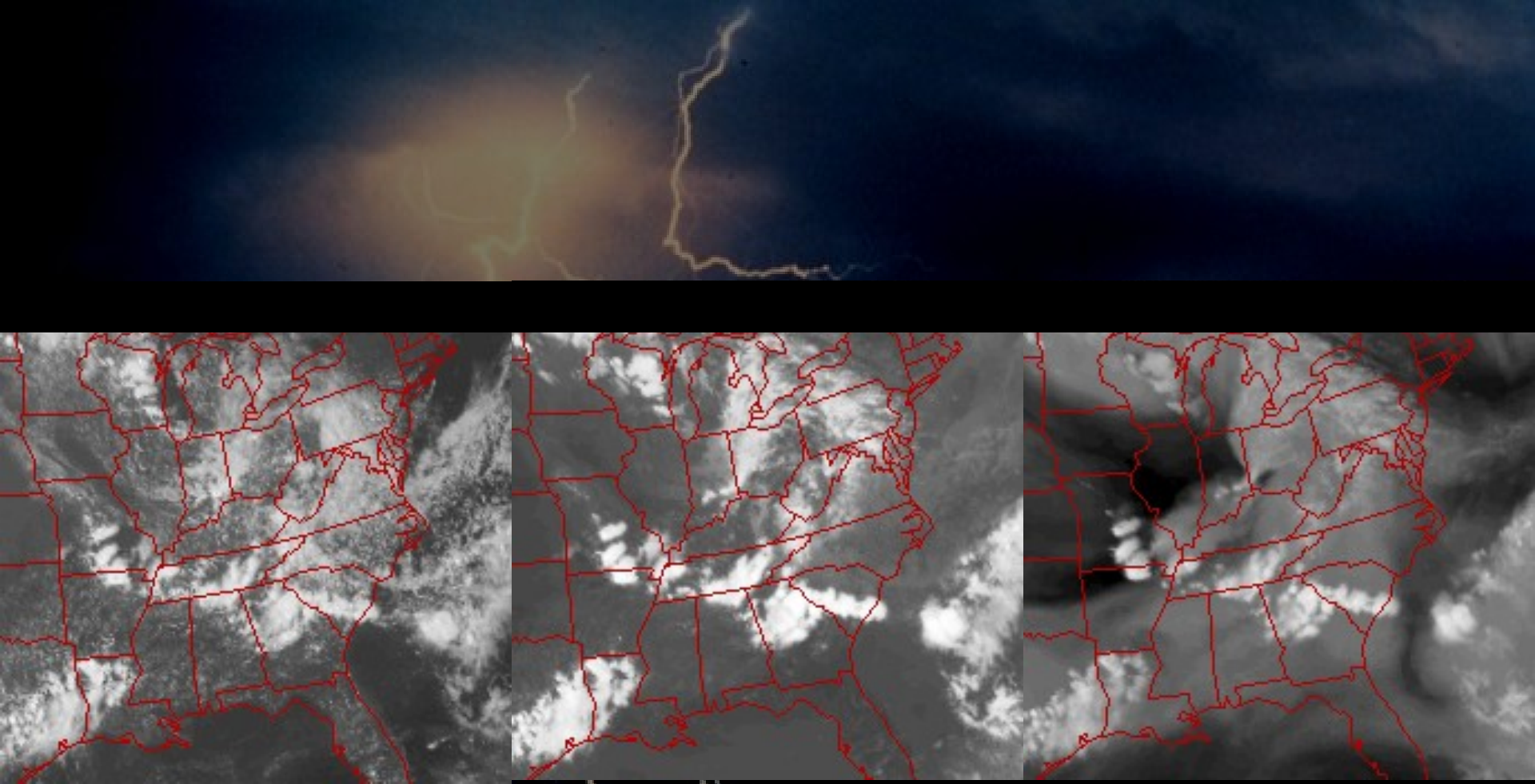
Visible: Cirrus blends in;
IR: Cirrus stands out.



GOES IR



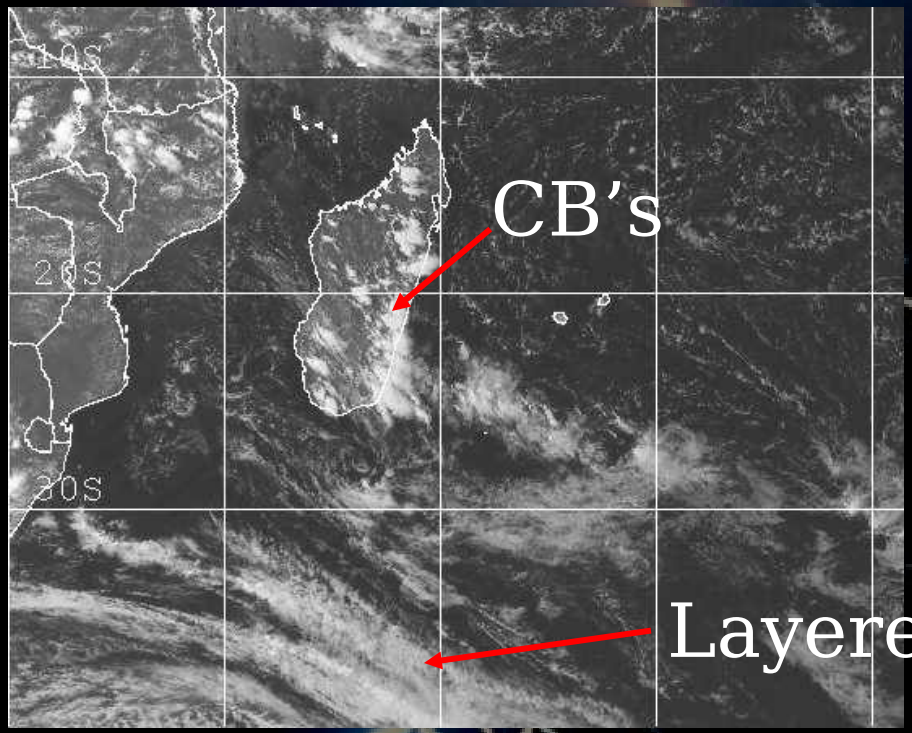
Visible: Snow cover stands out;
IR: Snow “blends in”



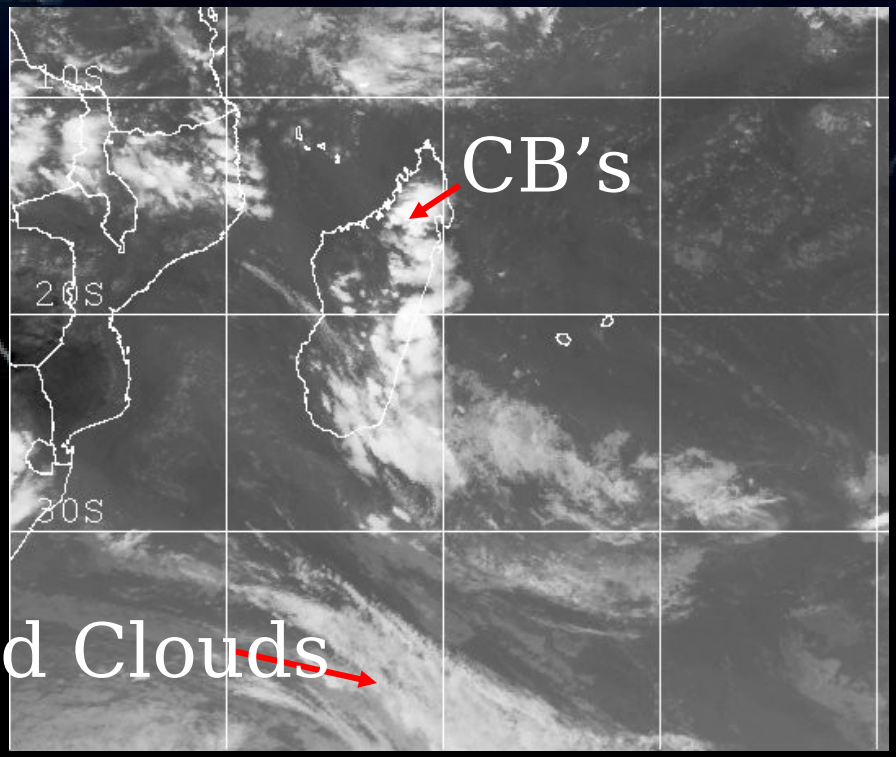
Cloud Typing

METEOSAT 5 Southern Hemisphere

Visible

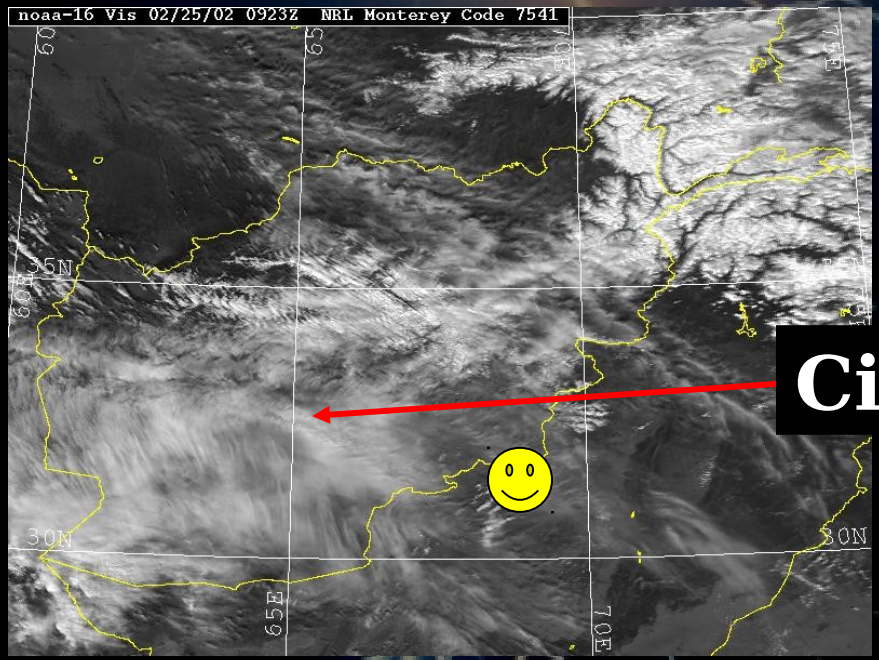


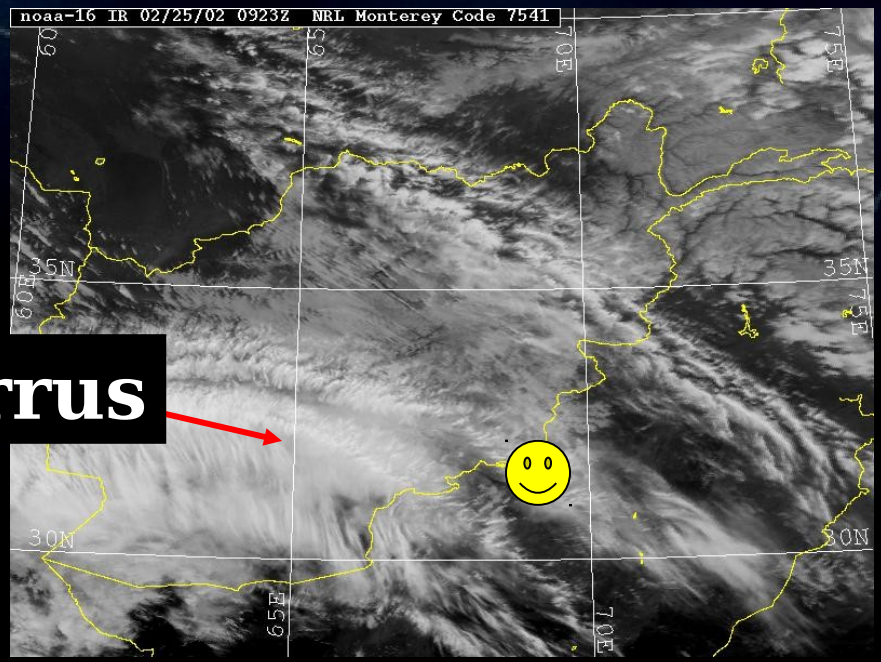
IR



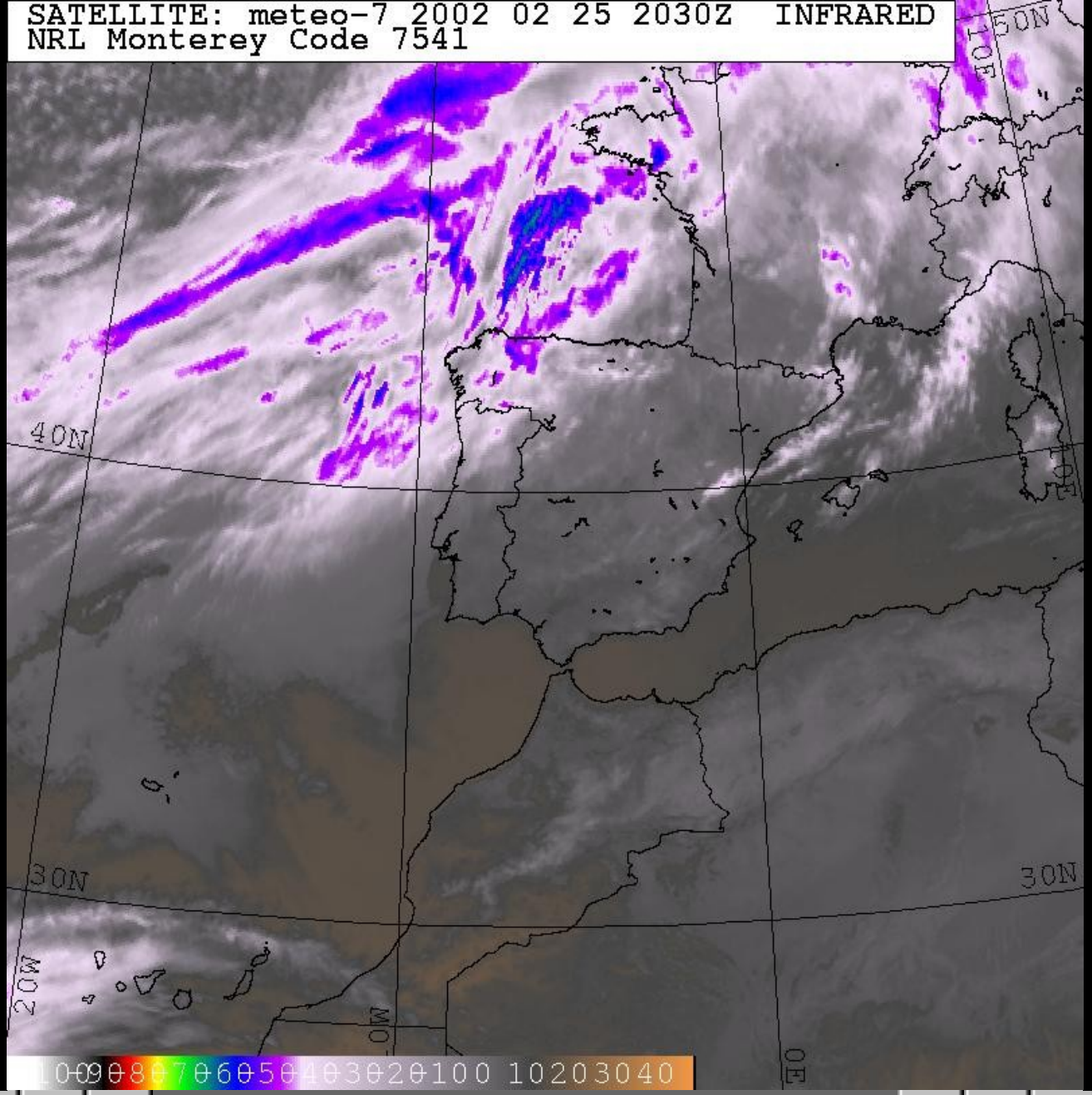
Visible

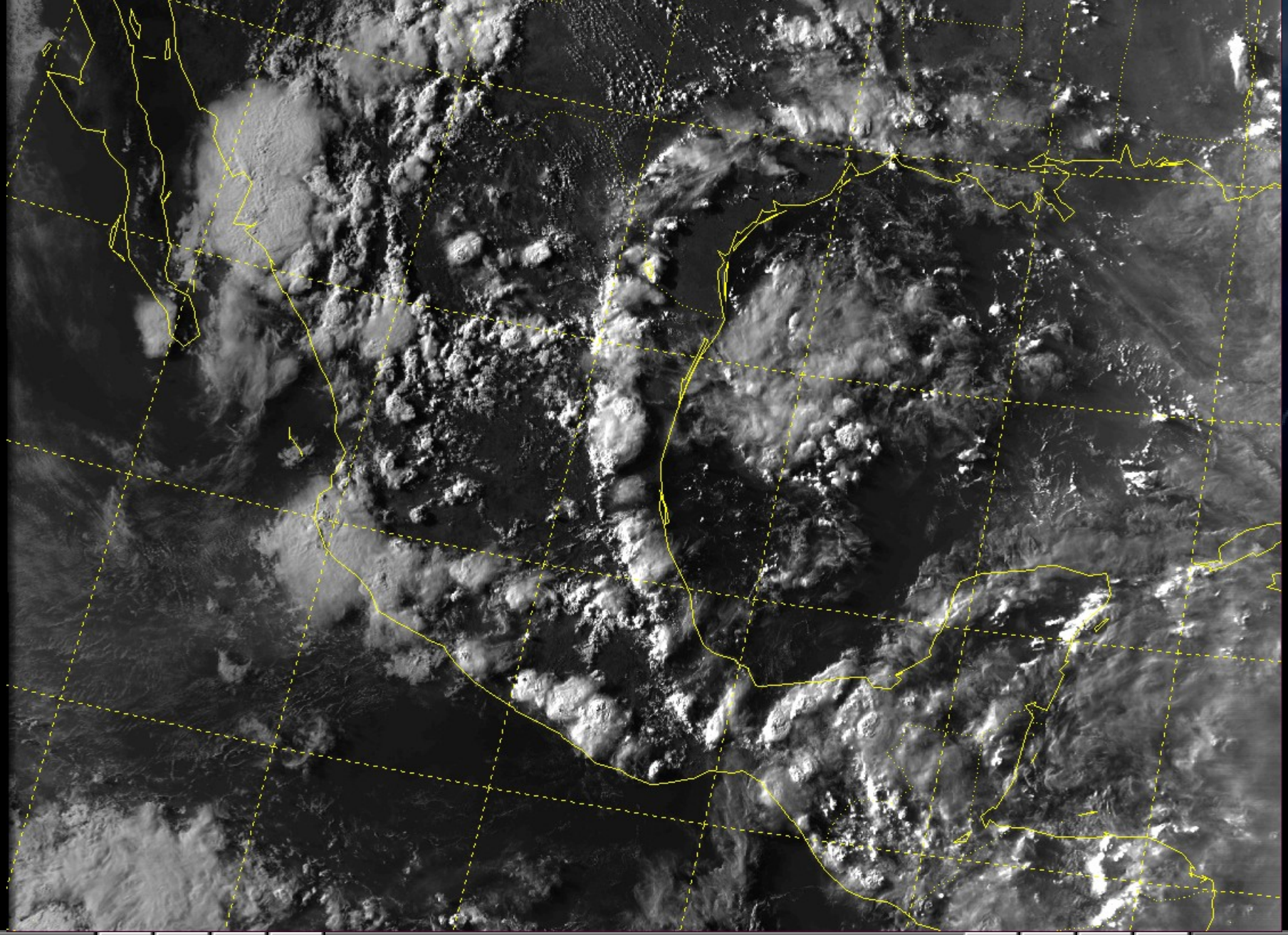
IR

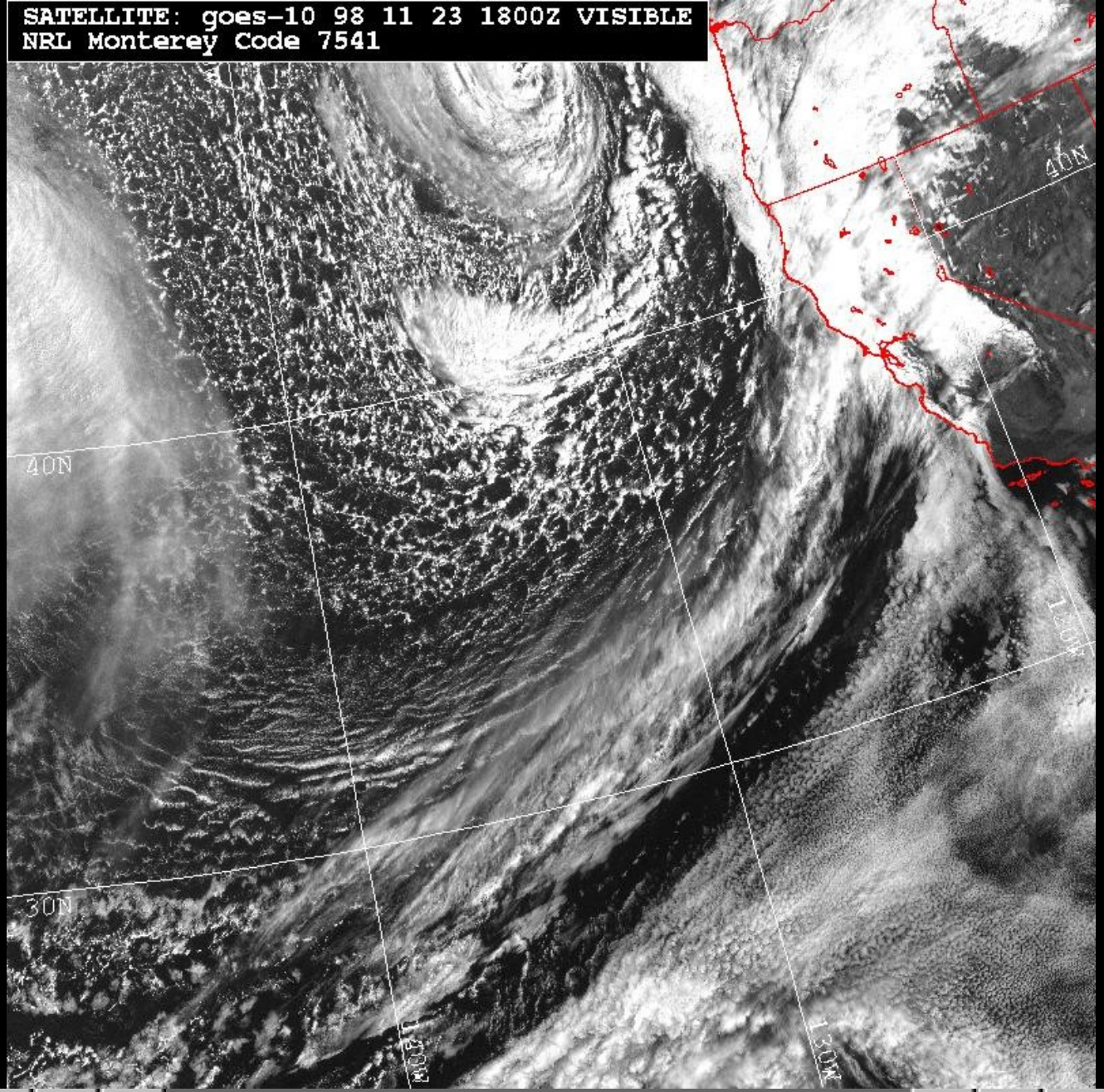


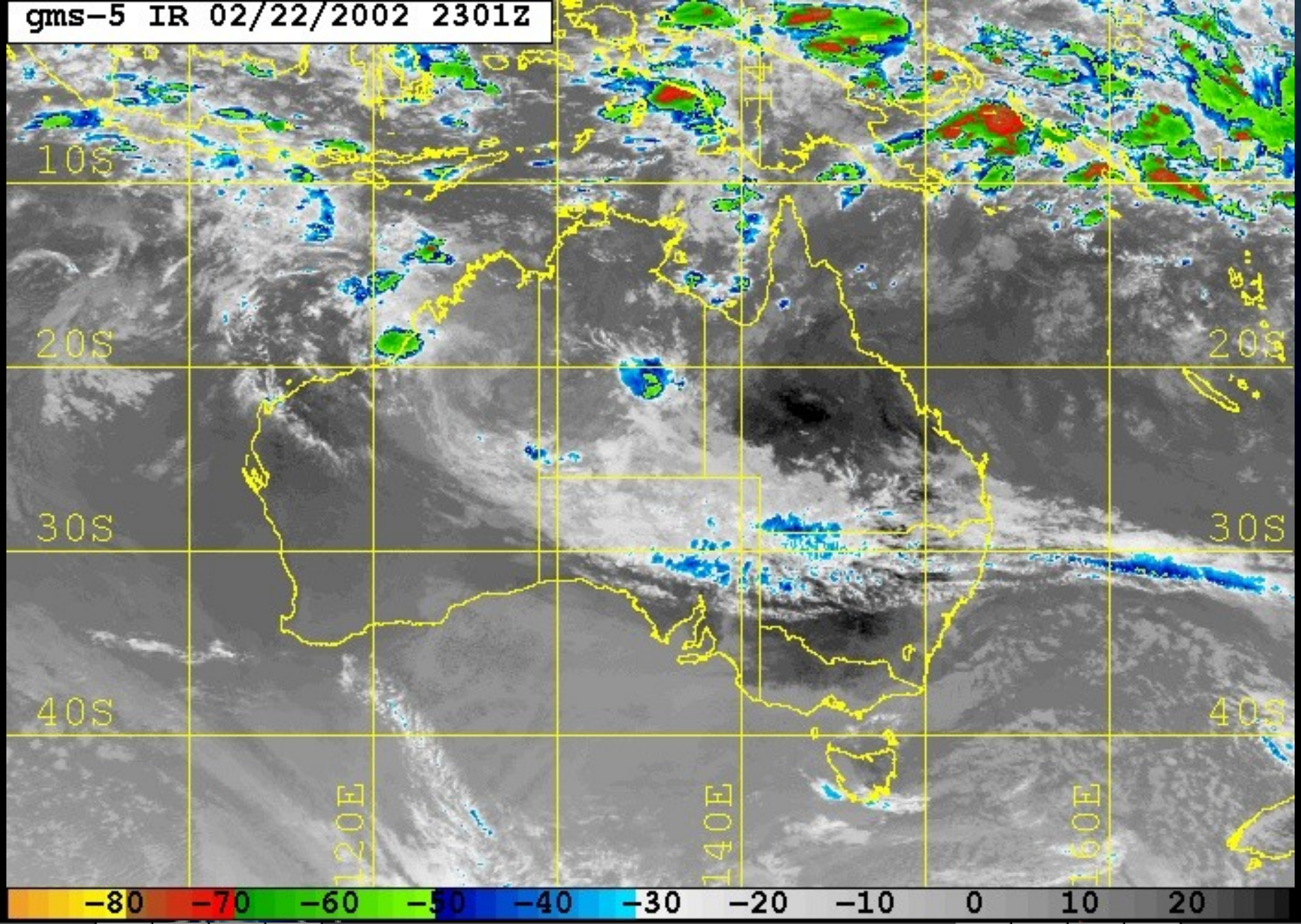


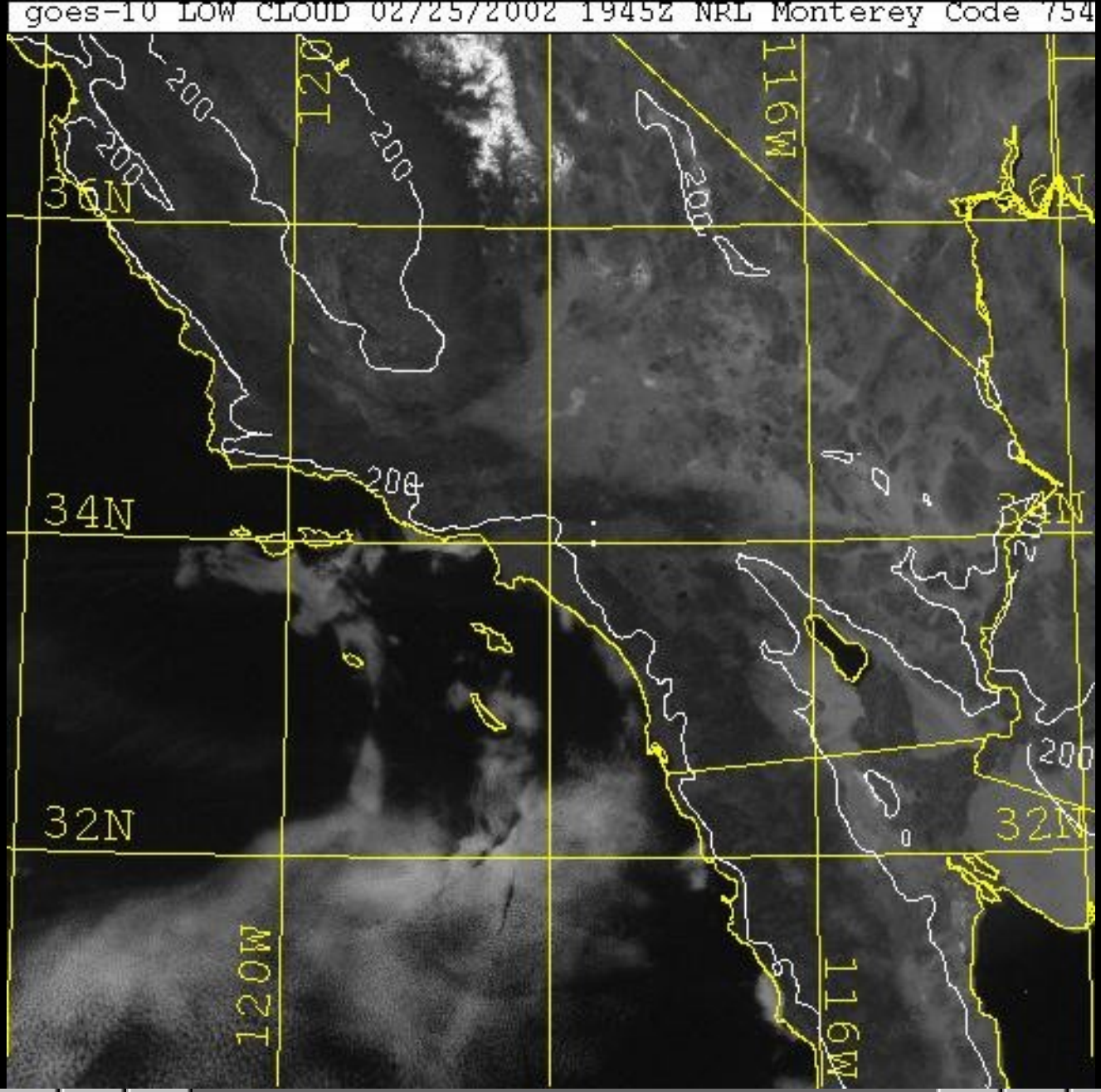
Cirrus

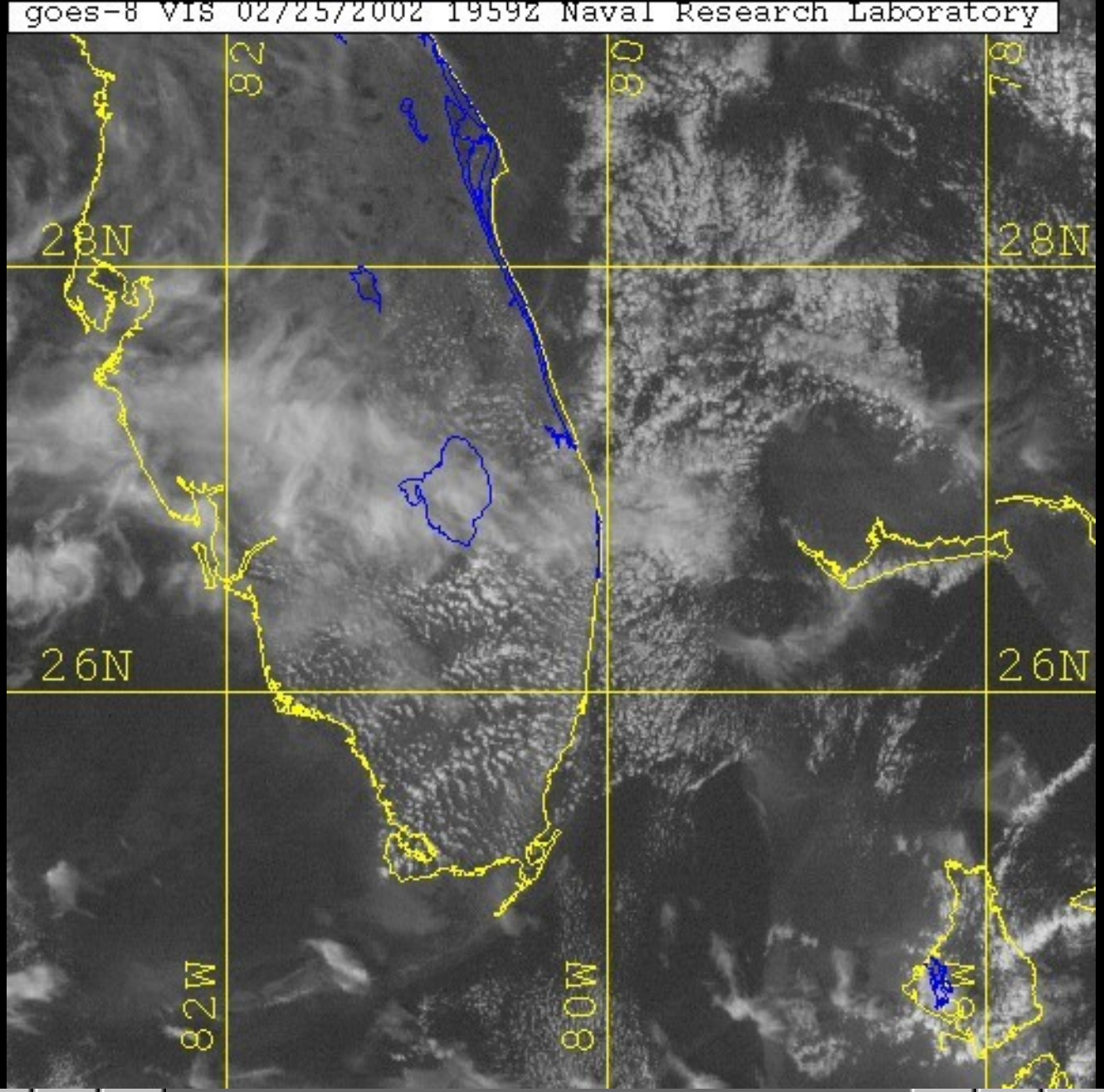

SATELLITE: meteo-7 2002 02 25 2030Z INFRARED
NRL Monterey Code 7541
50N
40N
30N
30N
20W
10W
0E
10 09 08 07 06 05 04 03 02 01 00 10 20 30 40

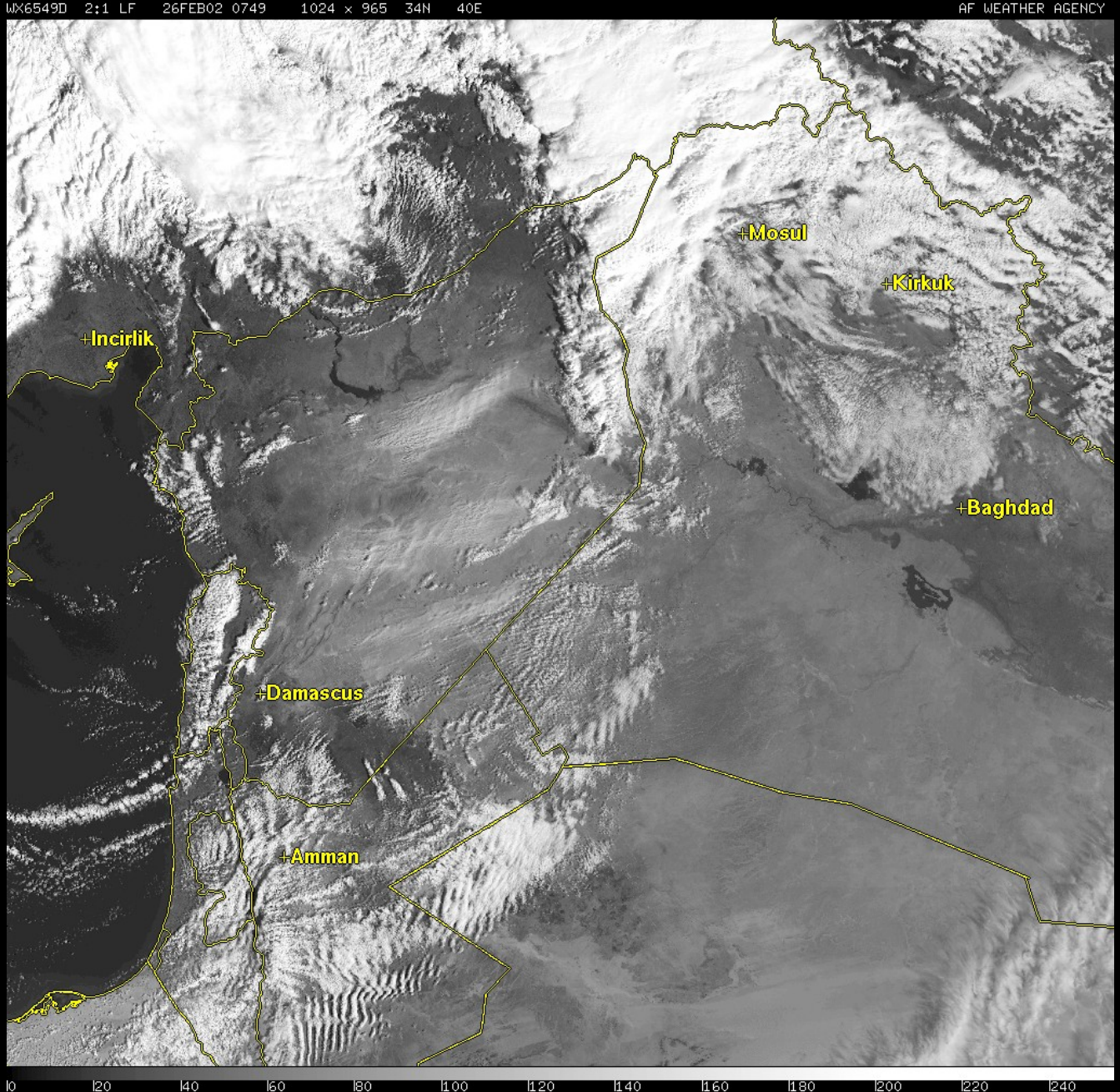



SATELLITE: goes-10 98 11 23 1800Z VISIBLE
NRL Monterey Code 7541
40N
40N
30N
130W
130W


gms-5 IR 02/22/2002 2301Z
10S
20S
30S
40S
120E
140E
160E
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20


goes-10 LOW CLOUD 02/25/2002 19452 NRL Monterey Code 754
200
200
200
200
200
120
116W
36N
34N
32N
120W
116W


goes-8 VIS 02/25/2002 1959Z Naval Research Laboratory
82
80
28N
28N
26N
26N
82W
80W


WX6549D 2:1 LF 26FEB02 0749 1024 x 965 34N 40E
AF WEATHER AGENCY
+Mosul
+Kirkuk
+Incirlik
+Baghdad
+Damascus
+Amman
0
20
40
60
80
100
120
140
160
180
200
220
240

Summary

- Satellite Concepts
- Introduction to Theory
- Visible and Infrared Image Interpretation

Questions

- APPLICATION: Assign Review Exercise 5.

- EVALUATION: Administer and evaluate Appraisal 302e. Give the Written Test at the end of the unit.